Comparative evaluation of homogeneity and quality of obturation by different obturation techniques using Cone Beam Computed Tomography-an *in vitro* study

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This Dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, *in partial fulfillment for the degree of* **MASTER OF DENTAL SURGERY** in **CONSERVATIVE DENTISTRY AND ENDODONTICS -BRANCH IV.** *It has not been submitted partially or fully for the award of any other degree or diploma.*

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This is to certify that this dissertation entitled **"Comparative evaluation of homogeneity and quality of obturation by different obturation techniques using Cone Beam Computed Tomography-an *in vitro* study"** is a bonafide research work done by **Dr. S.Sherin Menaka** under the guidance of **Dr. A.Arvind Kumar, M.D.S.**, Professor**,** Department of Conservative Dentistry and Endodontics, Rajas Dental College and Hospital, Kavalkinaru, Tirunelveli-627105.

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LIST OF ABBREVIATIONS

ANOVA	Analysis Of Variance
AV	Area of Voids
BF	Back Filling
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
CWCT	Continuous Wave Condensation Technique
µ-CT	Micro CT
DICOM	Digital Imaging and Communications in Medicine
EDTA	Ethylene Di amino Tetra Acetic acid
FOV	Field of View
GF	GuttaFlow
GP	GuttaPercha
HOCl	Hypochlorous acid
MS	Microseal
MDCT	Multi Detector Computed Tomography
MSCT	Multislice CT
NaOCl	Sodium hypo chlorite
OII	Obtura II
OCl	Hypochlorite
PGCA	Percentage of Guttapercha filled Canal Area
RES	Resilon Epiphany System
SPSS	Statistical Package for Social Sciences
TF	ThermaFill

TH	Taggers Hybrid
WVC	Warm Vertical Condensation
WL	Working Length
VP	Volume Percentage
VV	Void Volume

Background

Newer materials are emerging in the field of endodontics which can be used as root canal filling materials. Most of them are able to provide an adequate coronal and apical seal which is one of the prime requisite's for successful endodontic therapy. This *in vitro* study was done inorder to evaluate the homogeneity and quality of four obturating techniques namely, Lateral Compaction, Guttaflow, Beefill and Thermafill using Cone Beam Computed Tomography.

Materials and methods

One twenty (120) lower first premolars extracted for orthodontic purposes were used for this study. For the standardization of samples, teeth with single canals and straight roots were selected. The selected teeth were then stored in 5.25% sodium hypochlorite solution for two hours in order to dissolve the attached periodontal ligament fibers. After, which the teeth were made free of calculus and debris by using an ultrasonic scaler and the samples were washed under normal tap water and stored in normal saline solution at 37^0C and 100% humidity. The access cavities were prepared by using an endo access bur and the working length was estimated with the help of routine radiographs.

The canal shaping was done by using the protaper rotary file system upto size 30 by following the crown down technique. 2.5ml of 2.5% Sodium hypochlorite solution was used as the irrigant in between the filing sequences followed by 5ml of 17% EDTA solution and then 2.5 ml of saline was as the final flush. Then a preoperative CBCT analysis was done in order to evaluate the volume of the root canal after standardizing the working length at 15mm. This 15mm is further divided into coronal, middle and apical segments of 5mm each. These 5mm segments were

further divided into 0.5mm slices. The prepared root canals were then dried with appropriately sized paper points. AH plus sealer was coated along the walls of the prepared canals by using a lentulospiral at a speed of 300 rpm. Before obturation, the samples were randomly divided into four groups where group I was obturated by Lateral Compaction technique (LC), group II was obturated with Guttaflow (GF), group III was obturated with Thermafill (TF) and group IV was with Beefill (BF) by following the manufacturer's instructions.

Then, the postoperative CBCT analysis was performed by using the CBCT scanner (ORTHOPHOS XG 3D, Sirona Dental systems, Bensheim, Germany). The volume of each segment was then calculated from the linear measurements obtained by the CBCT analysis. The volume of the root canal in each slice was then calculated by multiplying the root canal area with the slice thickness (0.5mm).The Volume Percentage of the voids in the obturated root canal (VP) was calculated by using the formula, (R-V) ×100/R where, R is the volume of the root canal space and V is the volume of the void space. From this formula the volume percentage of the obturated material was calculated. The homogeneity of obturation was then evaluated by estimating the prevalence of voids at the coronal, middle and apical segments of the obturated root canals.

Statistical analysis

The obtained data was then analyzed statistically by using the Statistical Package for Social Sciences, (SPSS) version – 17 Software for Windows. Data entry was done by using the Microsoft office Excel spreadsheet where the data was expressed in its mean and standard deviation and were then analyzed by using ANOVA and multiple comparisons by Post Hoc Bonferroni test.

Results

Voids were present in all the groups (LC, GF, TF and BF) but the results were not statistically significant. In the intergroup comparison of the overall total volume percentage between the four groups, the mean overall total volume percentage of the Lateral Compaction group (LC) was the lowest at 88.9407% and Beefill (BF) at 97.9273 % was the highest, which was statistically significant. The overall volume percentage of the obturated material was the highest in the Beefill (BF) group followed by Thermafill (TF), Guttaflow (GF) and the Lateral Compaction techniques (LC). For the presence of extrusion among the four groups, the mean value for Lateral Compaction was 3.07 and for Beefill it was 1.033 which was statistically significant.

Conclusion

Within the limitations of the present study, it can be concluded that

1. Voids were present in all the four groups (LC,GF,TF,BF).
2. The maximum volume percentage of obturated material was found in the Beefill group (97.9273%) and the least volume percentage was found in the Lateral Compaction technique (88.9407%)
3. Extrusion was present in the Lateral Compaction group (3.07 %)
4. The homogeneity and quality of obturation was better in Beefill followed by Thermafill, Guttaflow and finally by Lateral Compaction.

Keywords:

Cone Beam Computed Tomography, Guttaflow, Lateral Compaction, Obturation Technique, Volumetric Analysis.

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Endodontic therapy aims at shaping and cleaning of the root canal system followed by the three-dimensional obturation of the root canal space. Success of the root canal treatment depends upon the triad of thorough canal debridement, effective disinfection and three dimensional obturation of the root canal space. Hence an ideal root canal filling is one which three-dimensionally fills the entire root canal space as close to the cemento-dentinal junction as possible[1].Obturation of the root canal space also helps to eliminate most of the avenues associated with leakage from the oral cavity and also from the periradicular tissues into the root canal system[2]. Since some persistent microorganisms may remain inside the root canal system even after instrumentation, a tight apical seal is desired in order to prevent the bacteria and their by-products from invading the root apex[3].The presence of micro-organisms, their toxins and metabolites results in the loss of vitality of the pulp and also leads to the subsequent formation of periradicular infection. Inability to eliminate one or all of these etiologic factors is one of the prime reasons for the failure of the root canal therapy.

Microleakage is defined as "diffusion of the bacteria, oral fluids, ions and molecules through the tooth and the filling material interface" or it is defined "as the clinically undetectable passage of bacteria, fluids and molecules or ions between the tooth and the restorative material[3]." Microleakage in the root canal space occurs when a fluid passes from the oral cavity into the tooth via the interface between the dentin and the core obturation material or the sealer. It can also occur due to the lack of adequate coronal as well as apical seal. When a perfect coronal as well as apical seal is achieved, the microorganisms present in the root canal are deprived of the essential nutrients needed for their growth and survival. Hence, one of the most important role of obturation is to provide a three dimensional hermetic seal for the root canal space from both coronal and apical leakage, thereby prolonging the longevity and the functional sucess of the endodontically treated tooth.

Coronal microleakage which may occur due to an inadequate coronal seal or due to the inadequate obturation of the root canal causes failure of the endodontic therapy. When there is no proper coronal seal, seepage of saliva and the penetration of the microorganisms from the oral cavity may result in apical periodontal inflammation. It is because of these reasons that, it is preferable for endodontically treated teeth to be restored by a direct filling or by a prosthetic crown within thirty days after the completion of root canal obturation[4]. Presence of voids in the obturated root canals may also lead to apical as well as coronal microleakage.

McComb and Smith in the year, 1975 observed under SEM that the instrumentation of the root canals with K-files, reamers, and giromatic reciprocating files created a smear layer[5]. Removal of the smear layer prior to obturation had been advocated by Guttman in the year 1993[6]. According to **The American Association of Endodontists (1994) in the glossary of Contemporary Terminology for Endodontics,** the smear layer has been defined as the "surface film of debris retained on the dentin or on tooth surfaces like enamel and cementum after the instrumentation with either rotary instruments or endodontic files". Studies have also shown that the smear layer present on the dentinal walls of the instrumented root canals covered the dentinal tubules by forming smear tags[7].

It has been reported in endodontic literature that in earlier times, root canals have been filled with a variety of materials like amalgam, asbestos, balsam, bamboo, cement, copper, gold foil, iron, lead, oxy-chloride of zinc, paraffin, pastes, plaster of paris, resin, rubber, silverpoints and tin foil[8]. All these materials which were used in the earlier times were not considered as the ideal root canal filling materials due to certain deficiencies in their properties as well as handling characteristics. Later, gutta-perchangained acceptance and is now considered as an almost ideal root canal obturating material.

Gutta-percha is primarily derived from the tree named as Palaquium gutta bail[8]. These trees are the natural inhabitants of South East Asia, particularly Malaysia and Indonesia. Gutta-percha is a transisomer of poly isoprene. The chemically pure gutta-percha exists in two distinctly different crystalline forms, alpha(α) and beta(β).These two different forms are inter convertible. Natural gutta-percha which is obtained directly from the tree is in the alpha (α) form but the commercially available gutta percha is in the beta (β) form[9].The alpha (α) form is tacky and sticky whereas the beta (β) form is solid, compactible and elongatable.

Gutta-percha was first introduced to dentistry as a temporary filling material by Edwin Truman in the year 1847[10]. Later Bowman used guttapercha as a root canal filling material in the year 1867. From then on, gutta percha has been widely used in endodontics and is still considered to be the most ideal root canal filling material[11].The standard root canal filling is a combination of the sealer with a central core material, where the core material until now has been mostly gutta-percha. At times there are chances that, the filled gutta-percha extrudes from the apical foramen and contacts the periapical tissues.

Guttapercha exhibits minimal toxicity and minimal tissue irritability. It is proved to be the least allergenic material available when retained within the root canal system. Even in the case of inadvertent gutta-percha overextension into the periradicular tissues, it is well tolerated, provided that the root canals are cleaned and sealed properly[13]. Various modifications to gutta-percha have been made available like the thermo mechanically compactible gutta-percha, the thermo plasticized gutta-percha with a solid core system, injectable guttapercha, medicated gutta-percha and the cold free flow gutta-percha. The beta (β) form of gutta-percha is used in the Lateral Compaction Technique due to its improved stability, hardness and reduced stickiness. The alpha (α) phase of gutta-percha is used in the thermoplasticized obturation techniques due to its low viscosity and flow properties resulting in a more homogenous root canal filling[14].Several obturation techniques are now being practiced in the field of endodontics, among which the Cold Lateral Condensation technique has been considered as the gold standard. Lateral condensation (compaction) of gutta-percha has been shown to be a successful technique if the adequate spreader depth of 1mm is achieved apically[15]. One of the potential shortcomings associated with Lateral Compaction is the relative poor replication of the root canal walls and the tendency to form voids as well as the creation of spreader tracts between the filled gutta- percha points[15].

Schilder popularized the Vertical Compaction of warm gutta-percha technique in the year 1947[16]. He used heat to thermoplasticize gutta-percha and pluggers to pack the softened gutta percha into the prepared root canal[16]. The use of heated gutta percha improves the homogeneity of the filling mass and also provides better adaptation to the dentinal walls of the root canal. The advantage of the thermoplasticized vertical compaction technique is the ability to soften gutta-percha so that it can easily flow into the accessory canals. But the main disadvantage associated with this technique is the extrusion of the obturation material beyond the apex. The Thermafill obturation technique is another carrier based obturation system developed by Dr. W. Ben Johnson in the year 1978[17].Thermafill obturators have been modified and now it forms an integral part in the obturation of the root canals.

Thermafill obturation technique provides a better seal as well as good adaptability to the root canal walls. In this technique, the Thermafill carriers are heated in an oven and then introduced into the root canal along with the plastic core[18]. The Thermafill core carrier system has the quality of compression and hence they uniformly adapt within the root canals forming an adequate seal. The heated Thermafill core carrier system allows for better penetration and flow of guttapercha, forming numerous gutta-percha tags inside the dentinal tubules[19].

The Continuous Wave of Condensation is another obturation technique introduced by John.T. McSpadden in the year 1980, which uses a plugger attached to a heat source. The heated plugger is used to vertically compact the gutta-percha. The major advantage of this technique is that, less time is required to downpack the thermoplasticized gutta-percha into the root canal space. Warm Vertical Compaction of guttapercha was introduced in the year 1977 by Yee *et al*[20]. Beefill is an injectable thermoplasticized device which works on this technique. Obturation by using the Beefill system resulted in a better three dimensional obturation of the root canal space including, flow of the filling material into the lateral canals and a minimal risk for root fracture[21].

To overcome the disadvantages associated with the thermoplasticized gutta percha systems namely 'shrinkage' and apical extrusion, a shrinkage free root canal obturating material known as Guttaflow was introduced in 2004, by Coltene/Whaledent Inc. (Cuyahoga Falls, Altstatten, Switzerland).This is a cold flowable, self-cure filling material for the root canals which combines the beneficial properties of both the sealer and the gutta percha. Guttaflow is a modification of the RoekoSeal Automix. Guttaflow has been proved to provide a consistent and adequate seal of the root canal space over a period of 18 months[22]. It also has other advantages associated with the thermoplasticized gutta percha systems like forming a homogenous mass and it also exerts less stress on to the root surface. Guttaflow exhibits increased flowability and adaptability to the root canal walls due to its smaller particle size. It also expands slightly by 0.2% when it sets. As it is in the fluid form at room temperature, it flows easily into the lateral canals [23].

Certain defects such as voids, spreader tracts, incomplete fusion of the gutta-percha cones and the lack of surface adaptation have been reported with all these obturation techniques. Based on a systemic review by Ng.Y.L it was concluded that, root canal filling with no voids and an obturation within 2 mm of the apex are the major factors affecting the efficacy of primary root canal treatment[24].The quality of the root fillings have been assessed through different experimental approaches such as the acid dissolution of roots, electro chemical method, fluid filtration, dye penetration, radiographs, sections of the sample, the SEM analysis of the interface between the filling material and the canal wall, radioisotope bacterial leakage, microscopic analysis, Cone beam computed tomography(CBCT) and Micro-Computed Tomography (μ-CT)[25-31].

Computed Tomography and Micro Computed Tomography are currently considered as the leading diagnostic tools for endodontic research. Thus CBCT has been successfully utilized in endodontics for the three dimensional reconstruction of the affected teeth[32,33]. CBCT measurement tools also provide satisfactory information about the linear distances within an anatomic volume. Thus CBCT has been proved to be a highly accurate and non-destructive diagnostic tool.

Hagay Shemesh *et al* have compared the differences in image interpretation by using CBCT, conventional periapical radiography and digital radiography in cases of root perforations and concluded that CBCT is a better diagnostic tool compared to periapical radiograph to diagnose strip perforations[34]. During radiographic assessment, there is a possibility of interferences from the artifacts caused by the difference in densities associated with the endodontic materials used. This may cause errors in the interpretation of images taken by the radiographic techniques but CBCT is considered to be more accurate[35].

Reconstruction software programs can be used to provide secondary reconstruction images in three orthogonal planes[36] (axial, sagittal and coronal). The term pixel is used to refer a single scalar element of a multi-component representation of the image and a voxel represents a single sample or data point on a regularly spaced, three dimensional grid. In CBCT the voxel resolutions are isotropic, which means that it is equal in all the three dimensions. The resolution and the details of CBCT imaging is determined by the individual volume elements or voxels produced from the volumetric dataset. In CBCT imaging, voxel dimensions are primarily dependent upon the pixel size which is present on the area detector and not as in conventional CT were it depends upon the slice thickness.The CBCT provides images of high contrasting structures like the osseous structures of the craniofacial area. The other advantages of CBCT include rapid scan time and reduced radiation dosage. In endodontics CBCT is used for the identification of different anomalies associated with the root canals and also for the determination of root curvature[37]. It is also used in the diagnosis of periapical pathosis and also in cases where there can be anatomic superimposition of the adjacent roots[37]. It is proved to be a valuable tool in diagnosing the quality of root canal obturation and also in detecting for the presence or absence of voids in the obturated material.

CBCT is a valuable tool in assessing the postoperative endodontic treatment complications like overextended root canal obturation material or the presence of separated endodontic instruments. It is also used for the localization of the perforation sites in the root canals and also in the identification of calcified canals. CBCT helps in the diagnosis and management of dento alveolar trauma like crown root factures and alveolar fractures. Localization and differentiation of external root resorption from that of internal root resorption or invasive cervical resorption from other conditions can also be diagnosed using CBCT. CBCT is also used for the presurgical planning in determining the exact location of the root apices and also to evaluate the proximity of adjacent anatomical structures. The CBCT data acquired can be exported in the non-proprietary DICOM (Digital Imaging and Communications in Medicine) file format[38].This file format is a standard format for handling, storing, printing and transmitting information in medical imaging. This blossoming field provides opportunities for the practitioners to combine the use of CBCT for diagnosis and also to evaluate the quality of obturation and to detect for the presence of voids.

In this *invitro* study the homogeneity of obturation of the root canals obturated by using four different obturation techniques namely the Lateral Compaction Technique, Guttaflow or cold free flow obturation technique, the Thermafill obturating system and the Beefill obturating system were evaluated for the presence of voids, extrusion and for the quality of the obturation using CBCT as the diagnostic tool.

AIM

To evaluate the homogeneity and the quality of obturation using the different obturation techniques namely - Lateral Compaction, Guttaflow (Coltene, Whaledent, Germany), Thermafill (Dentsply, Tulsa Dental Specialities-Tulsa) and Beefill (VDW,GmbH, Bayerwaldstr, Munich, Germany) by Cone Beam Computed Tomography.

OBJECTIVES

- To compare and evaluate the quality and homogeneity of obturation
- To detect the presence of voids
- To evaluate for the presence of extrusion.

NULL HYPOTHESIS

There is no difference in the homogeneity as well as in the quality of the obturation among the different obturation techniques.

Da Silva. D *et al (*2002)[39] evaluated the quality of root canal fillings obturated by lateral condensation (LC), Thermafil (TF) and Thermafil as backfilling (BF). Sixty curved canals were prepared with the ProFile system to size 0.04 taper in the apical half and to 0. 06 taper in the coronal half. This study consists of three groups. After verifying the apical patency with a size 15 K-file, the canals were filled using three different techniques, Lateral Condensation (20 canals), Thermafill (20 canals) and Thermafill as back filling. Resin-based sealer was used as the root canal sealer. Then the root fillings were assessed by both stereomicroscopy for material extrusion and digital radiography for the occurrence of voids. The results showed that, extrusion of both gutta-percha and the sealer occurred in all the 20 canals filled with the Thermafill technique. But only a few cases of sealer extrusion were detected with Lateral Condensation and Thermafill as backfilling techniques. No voids were detected in this study in the TF group, whereas small voids were detected in the LC and BF groups.

Bailey *et al* (2004)[40] assessed the quality of root canal obturation using Cold Lateral Condensation in adjunct with ultrasonics. About 10 groups consisting of 15 teeth in each group were selected in which 9 groups served as the experimental groups (ultrasonic condensation) and the 10thgroup served as the control group (Cold Lateral Condensation). An extracted human maxillary canine was used as an *in vitro* split tooth model to allow repeated obturation of the same root canal system using an ultrasonic device to thermo compact the gutta-percha without sealer. After each obturation, the root filling was removed from the tooth and its quality was then evaluated. The voids present within the body of the root filling as well as on the surface were measured. The results showed that the ultrasonic condensation of gutta percha was more effective when compared to Cold Lateral Condensation.

Nimet Gencoglua (2007)[41] investigated teeth filled with six different gutta-percha techniques, the Thermafil, JS Quick-Fill, Soft Core, Microseal, System B and Lateral Condensation. About 60 extracted single rooted teeth were selected. The coronal part of each tooth was removed and the root canals were prepared by the step-back technique. The prepared roots were randomly divided into six groups of 10 teeth, filled by one of the obturation techniques and Kerr sealer. The teeth were then kept in 100% humidity. After this period, apical parts of the root (10±0.05 mm) were attached to the computerized fluid filtration meter. Thermafil, Soft Core,Quick-Fill and System B techniques showed lower leakage than Microseal and Lateral Condensation.

Madfa(2007)[42]compared Warm Vertical Compaction technique with the Lateral Compaction technique for obturating the root canals. A polymer-based resin system or gutta-percha was used for obturation and the quality of obturation was evaluated. About 64 mandibular premolars were instrumented, irrigated and divided into four groups. The teeth were then obturated using Lateral Compaction and a resin sealer, Lateral Compaction with gutta-percha and AH Plus sealer, Warm Compaction with resin sealer and Warm Compaction with gutta-percha. One specimen from each group was randomly chosen for SEM evaluation. It was longitudinally sectioned and the dentin-filling interface was examined. The results showed that gaps were observed between the sealer and the filling and also between the sealer and the dentin in roots filled with guttapercha, whereas there was no evidence of gaps in roots obturated with resin sealer.

Lipeng *et al* (2007)[43] evaluated the clinical outcome of root canal obturation which was done by warm gutta-percha (GP) or Cold Lateral Condensation (CLC) techniques by a systematic review and meta-analysis. Postoperative pain, obturation quality, overextension and long-term outcomes were the few parameters that were evaluated. It was concluded that warm gutta percha obturation demonstrated a higher rate of over extension than Cold Lateral Compaction but the postoperative pain prevalence, long-term outcomes, and obturation quality were similar between the two groups.

Daniela Mazotti *et al* (2008)[44] determined the quality of obturation using four different obturation techniques. The obturation techniques performed were active Lateral Condensation, a modification of Tagger's hybrid technique, ENAC ultra sound technique and the Microseal technique. One hundred and sixteen single-rooted human teeth were selected for this study. It was divided into four groups of twenty nine teeth each. After instrumentation, a cavity was made with a bur in the cervical, middle and apical thirds of the root canal in order to simulate the lateral canals. The quality of obturation was evaluated using photographs and radiographs. The quality of obturation was better for the Microseal technique than the modified Tagger's hybrid technique, ENAC ultrasound technique and the active Lateral Condensation technique.

Kandaswamy.D *et al* (2009)[45]compared Lateral Condensation technique, vertically compacted thermaplasticized gutta-percha technique and cold free-flow guttapercha (Gutta Flow) obturation techniques. Volumetric analysis was done using spiral CT. About 60 single rooted anterior teeth were selected for this study. After cleaning and shaping the teeth were obturated and volumetric analysis was done. It was concluded that cold free-flow obturation technique showed the highest volume of obturation, followed by the vertically condensed thermoplasticized technique and the least volume of obturation was observed in the Cold Lateral Condensation technique.

Mohammad Hammad (2009)[46] evaluated the percentage of volume of voids and gaps in root canals obturated with different obturation materials by using micro computed tomography. Forty eight single rooted teeth were collected and decoronated and the root canals were prepared by using rotary files. The roots were randomly allocated into four groups. Endorez points and Endorez sealer, Real seal points and real seal sealer and guttapercha points and guttaflow sealer were used for the obturation of the root canals. Then the roots were scanned with micro-CT and the volume measurements of the voids and gaps in the obturated roots were done using CT software. The percentage of gaps and voids were then calculated. The results showed that none of the root filled teeth were voids free. Roots filled with guttapercha had lesser voids and gaps compared to the roots filled with other technique.

Souza *et al* (2009)[47] determined the influence of the obturation technique and the root canal area on the Percentage of Gutta Percha (PGP) in laterally compacted root canals. Sixty extracted canine teeth were assessed and the root canals were instrumented and divided into three groups. After which the teeth were filled with laterally compacted gutta-percha cones and AH Plus sealer. A variation of Cold Lateral Compaction using a sequence of spreaders prior to the accessary cone placement was compared with the standard technique. The roots were then sectioned and the area of the root canal and gutta percha at each level was measured using autocad software and the PGP was calculated. According to this invitro study, variations in the root canal filling techniques and the canal area influenced the percentage of gutta-percha in laterally compacted root fillings.

Melek Akman (2010)[48] evaluated the presence of voids in roots obturated with three different sealers. Thirty extracted human single-rooted teeth were decoronated and instrumented. The teeth were then divided into three groups of ten each. Then the teeth were obturated using epiphany and Resilon, Metaseal with guttapercha and AH plus with guttapercha by the matching taper single cone technique. The mean areas of the gaps present between the sealer and the root dentin and also the void present inside the sealer was measured. Based on this study, it was concluded that there is no significant differences in the mean areas of gaps or voids among the tested resin-based sealers.

Borden (2010)[49] evaluated the percentage of gutta percha filled area in four different groups of maxillary lateral incisors. The canals were filled with guttapercha and AH 26 sealer using the Lateral Compaction technique or a combined lateral and Vertical Compaction technique. The area of the canal and the guttapercha was measured in each section and the Percentage of Gutta percha filled Canal Area (PGCA) was calculated. It was concluded that the combined lateral and Vertical Compaction technique achieved comparable percentage of gutta percha filled canal area in the evaluated root canals.

Bruno Carvalho Sousa (2010)[50] performed an *in vitro* quantitative laboratorial study to compare the ability of three filling techniques to fill simulated lateral canals. Thirty extracted single rooted human teeth were selected. After cleaning and shaping three lateral canals were created, one in each third. The teeth were then randomly separated into three groups, Continous Wave of Condensation (Group-I), thermo mechanical compaction (Group-II) and Lateral Condensation (Group-III).Then the teeth were crosss-sectioned and the images were obtained using a stereoscopic lens. The results of this study showed that, a greater number of simulated lateral canals were obturated in groups I and II.

R.Anbu (2010)[51] evaluated the efficacy of various obturation techniques using spiral computed tomography. Root canal treatment was done in 40 maxillary central incisors and divided in to four groups of 10 samples each and was obturated with Lateral Compaction, Thermafill, Obtura II, and system B techniques respectively. AH-Plus sealer was used as the root canal sealer. The filled volume in each canal was measured using spiral CT and the percentage of obturated volume (POV) was calculated. It was concluded that the four groups were comparable in canal volume and that Thermafill showed the highest percentage of filled volume of obturated material.

Swelleng Maria Cunha Santos (2010)[52] assessed radiographically the relationship between the quality of root fillings and the periapical status of the tooth. In this study, a total of 291 filled root canals were evaluated. The periapical status at follow up showed various changes like normal, slight apical widening of the periapical ligament or the presence of periapical lesion. The radiographic parameters of the quality of root filled canals showed a significant relationship with that of the periapical status of the tooth.

Kabbaz M.G (2010)[53] evaluated the radiographic quality of root fillings performed by undergraduate students. Endodontic records and periapical radiographs of 759 obturated teeth were selected. The two variables examined were the length and the density of the root fillings which was categorized as acceptable and not acceptable. The presence of ledges, root perforation, foramen perforation and fractured instruments were investigated. Acceptable root fillings were found in 55% of canals. More acceptable root fillings were found in the maxillary teeth compared to the mandibular teeth and in anteriors compared to the premolars.

Marina Angelica (2010)[54] determined the percentage of voids in the root canals obturated by 4 different obturation techniques. About fifty-two extracted maxillary lateral incisors were prepared using the crown-down pressure less technique. The teeth were randomly divided into 4 groups of thirteen samples each. The selected teeth were then obturated using, Lateral Compaction (LC), Tagger's hybrid (TH), MicroSeal (MS) and GuttaFlow (GF) techniques. Digital images of the root canals were acquired using a stereomicroscope and the images were analysed using the Image

Tool 3.0 software. A significant decrease in the gutta-percha filled area and an increase in the sealer filled area were observed at the apical level for all the evaluated techniques. With regard to the presence of voids, no significant difference was found among these four techniques. A larger gutta-percha filled area was present in the Lateral Compaction and the Guttaflow techniques at the coronal and middle third level.

Kavitha Anantula (2011)[55] compared the sealing ability between the conventional Cold Lateral Condensation technique, Obtura II and Guttaflow. About sixty single-rooted teeth were selected and the canals were shaped by ProTaper rotary files. The teeth were then separated into three groups each depending upon the type of obturation technique. Group A was obturated using the Lateral Condensation technique and AHplus sealer, Group B was obturated with Obtura II injection-molded thermoplasticized technique and AHplus sealer, Group C was obturated using GuttaFlow. After storing the teeth in 100% humidity for seven days at 370ºC, the roots of the teeth were sectioned at five levels. The sections were then observed under a stereomicroscope at 40 × magnification and the images were analyzed for determining the area of voids (AV) and the frequency of voids. The Obtura II, utilizing the injection-molded thermoplasticized gutta-percha technique had better adaptability to the root canal walls when compared to GuttaFlow and Lateral Condensation techniques.

Zaslansky. P *et al* (2011)[56] assessed the differences between the cross-sectional areas of the root canals and the obturated materials. Six roots filled with laterally compacted gutta percha and AH-26 sealer was scanned with phase contrast enhanced microtomography in a synchrotron facility. Reconstructed virtual slices were compared with sections of both wet and acrylic embedded roots. The different contrast of gutta-percha, voids, sealer and the root dentin were identified and correlated. It was concluded that phase contrast enhanced micro tomography revealed internal interphases and detailed 3D volumes of accentuated voids as well as micrometre sized particles and gaps within the treated roots.

MinaZarei *et al* (2011)[57] evaluated the effect of canal curvature on the adaptation of gutta-percha to the dentinal walls of root canals obturated using the Herofill obturating system. In this *invitro* study, 80 mesial roots of mature human first molars with length 16 mm and a curve between 5° and 45° and having no caries or resorption of the root surface were selected. A cone beam computed tomography system was used to evaluate the presence or absence of gaps in the samples. Photographs were taken in three sections: 2mm above the curve, at the curve and 2 mm below the curve. The gap area was identified using Photoshop and AutoCAD software. The results showed that, there was significant difference in the presence of voids between the two lateral condensation groups with different curves.

Brian.M.Gillean (2011)[58] compared the quality of root canal treatment versus the quality of coronal restoration in determining the treatment outcome. The treatment outcome categories were adequate root canal treatment (AE), inadequate root canal treatment (IE), adequate restoration (AR) and inadequate restoration (IR). The percentage of teeth without apical periodontitis was the criteria assessed for each category. On the basis of this study, the odds for healing in apical periodontitis increases with both adequate root canal treatment as well as adequate restorative measures.

Somma.F *et al* (2011)[59] determined the quality of obturation performed by two thermaplastized obturation techniques and a Cold Lateral Compaction technique using micro-CT. A total of 30 freshly extracted teeth were selected. Root canals were prepared with protaper rotary insruments and then the teeth are randomly divided into three groups. In group-I the canals were obturated with a single point technique, group-II with Thermafil and group III with System- B. AH-Plus sealer was used in all the three groups. Root fillings were assessed using a desktop X-ray micro focus CT scanner. The percentage of root filling materials and the presence of voids were calculated for each specimen and it was concluded that all the techniques produced comparable results in terms of both percentage of filling and the voids distribution.

Marciano M.A *et al* (2011)[60] compared the percentage of gutta -percha, sealer and voids and the influence of isthmuses in mesial root canals of the mandibular molars filled with different obturation techniques. Sixty mesial roots of mandibular first molars were prepared with ProTaper instruments to size F2 and filled using a single-cone, Lateral Compaction, System B or Thermafil techniques. An epoxy resin sealer which was labelled with Rhodamine-B dye to allow analysis under a confocal microscope was used. The percentage of gutta-percha, sealer and the area of voids were calculated at 2, 4 and 6 mm from the apex, using Image Tool 3.0 software. The results showed that at the 2 mm level the percentage of gutta-percha and the sealer as well as the presence of voids was similar amongst the System B, lateral compaction and single-cone techniques. The analysis of all sections (2, 4 and 6 mm) revealed that more gutta-percha and less sealer and voids were found in root canals filled with the Thermafil and the System B techniques. From this study, it was concluded that, gutta-percha and the sealer filled area as well as the presence of voids was dependent on the canal-filling technique.

Manjunnath .H (2011)[61] examined the appearance of uninstrumented recesses in oval canals after instrumentation using circumferential filing. The quality of obturation done by both the cold lateral compaction and thermo plasticized gutta-percha technique were evaluated. Twenty non-carious, freshly extracted human mandibular incisors with single canals were divided into group I (n=10) and group II (n=10) according to two different obturation methods. The sectioned roots were prepared with flexo files ranging from #15 to #40 by using circumferential filing. The obturated specimens were horizontally sectioned at 5 mm from the apex. Each section was observed under the stereomicroscope at x40 magnification. The quality of obturation in the recesses was evaluated by using the 3-point scoring system. It was concluded from this study that, the thermoplasticized obturation technique was better in filling the recesses as compared to Lateral Compaction.

Yu Hong Liang (2011)[62] evaluated the association between the technical quality of the root canal filling and the outcome of treatment. Among the 234 teeth (268 roots) that underwent root-canal treatment, the quality of root canal filling as well as the outcome of treatment was assessed by both periapical radiograph (PA) and Cone Beam Computed Tomography (CBCT) two years after the completion of the treatment. The presence of preoperative periapical radiolucency and the quality of root filling and coronal restoration was identified by both PA and CBCT as outcome predictors. The complete absence of post-treatment periapical radiolucency was observed in CBCT scans in 81% and 49% of satisfactory and unsatisfactory root fillings respectively as compared to 87% and 61% which was revealed by periapical radiograph.

Sandhiya Kapoor.P (2011)[63]Compared the apical microleakage of Resilon to Thermafil, Gutta-flow and Cold Lateral Condensation technique by using the dye penetration method. About sixty extracted human maxillary single rooted teeth with intact roots were selected. The teeth were then randomly divided into four groups for obturation. Group I – Cold Lateral Condensation with AH Plus, Group II - Gutta-flow with master cone, Group III– Thermafil with AH Plus and Group IV-Resilon with Selfetch epiphany. Apical microleakage was assessed by the dye penetration test under stereomicroscope. According to the results of this study Resilon provides good seal but Gutta-flow exhibited maximum microleakage.

Robert Hale (2011)[64] compared the outcome of primary endodontic treatment using a standardized cleaning and shaping technique. Endodontic treatment was performed on the patients using a standardized cleaning and shaping protocol and the root canals were obturated using a Lateral Compaction of gutta-percha (LC) or carrier-based obturation (CBO) technique. A total of 205 cases met the inclusion criteria. About 71 teeth in 60 patients were recalled after 2 years and were evaluated both clinically and radiographically. According to the results, there was no difference in the success rates between cases obturated with Lateral Compaction or Carrier based obturation techniques.

Mandana Naseri (2013)[65] compared the quality of four different root canal obturation techniques: Cold Lateral Condensation (CLC), Warm Vertical Condensation (WVC), Obtura II (OII) and Gutta Flow (GF) by using micro-computed tomography (micro CT). A total of 20 extracted maxillary first molars prepared with ProTaper files, were randomly divided into four groups. Micro CT was used to measure the internal volume of root canals. After obturation, new micro-CT images were taken and the Volume Percentage (VP) of voids, gutta-percha and the sealer at different levels were calculated with CT software. The highest percentage of filling material was observed in GuttaFlow group followed by ObturaII with no statistically significant differences. These two groups had significantly more acceptable filling than Warm Vertical Compaction and Cold Lateral Compaction groups. Voids were detected in all the samples. There was a significant difference between the highest and the lowest percentage of voids in Cold Lateral Compaction (19.6%) and Guttaflow groups (6.7%).

Bilal Bakht Ansari (2011)[66] compared the radiographic quality of obturation in molar teeth, obturated with Cold Lateral Condensation and thermoplasticized injectable gutta percha technique (Obtura II system).Sixty patients were equally divided into 2 groups, Group A obturated with Cold Lateral Condensation technique and Group B with Obtura II. Periapical radiographs were obtained immediately after the obturation using paralleling technique. The radiographs were examined by an observer, who was blinded to the group allocation. The results showed that both the groups were comparable in all respects and there was no difference in voids as well as in the apical termination of obturation.

Daniele Angerame *et al* (2013)[67] determined the quality of fillings in root canals shaped with Reciproc. The root canals of 60 single-rooted teeth were instrumented with Reciproc R40 and randomly assigned to four groups. (n = 15): G1single point; G2 as G1 + DT Light Post; G3continuous wave of condensation; G4 as G3 + DT Light Post. Data were statistically analysed by non-parametric test ($p < 0.05$). The voids present in the root fillings were quantified by micro-CT. A significantly greater percentage of internal voids were found in the group in which the root canal was filled by the Continuous Wave of Condensation technique (G3). The results of this study also proved that the voids were sporadic and distributed without regular patterns, except for the group G3, where voids were seen to be entrapped within the gutta-percha.

Shilpa H Bandhi (2013)[68] compared the sealing ability of three newer obturating materials like the GuttaFlow, Resilon Epiphany System (RES) and Thermafil, using silver nitrate dye and observing under stereomicroscope. Thirty single rooted teeth were divided into the following groups. Group I :GuttaFlow, Group II : Resilon /Epiphany sealer Group III : Thermafil with AH-Plus sealer. The teeth were decoronated and instrumented with the profile rotary system and then obturation was done. Apical seal was determined by dye penetration method using silver nitrate. Dye leakage was determined using the stereomicroscope. The results showed that Group II which consists of Resilon with Epiphany sealer showed the least amount of microleakage when compared to Group I - GuttaFlow and Group III which was Thermafil with AH-plus sealer. It was concluded that Resilon Epiphany system had a higher sealing ability followed by Thermafil and Guttaflow. .

L.Moeller (2013)[69] determined the presence of voids in root fillings performed in oval and ribbon shaped canals. Sixty-seven roots with oval and ribbon-shaped canals were prepared using Profile Ni-Ti rotary files. After which the roots were randomly allocated into two groups depending up on the root filling technique. Group 1 was filled by using Lateral Compaction Technique LCT (n = 34) and group II was filled using the Hybrid Technique HT (n = 33). Voids in relation to the root canal fillings were assessed by using cross-section images from the Micro Computed Tomography scans. All the root canal fillings had voids. There was no significant difference in the percentage of voids between the two root filling techniques.

M.Wolf (2013)[70] analyzed the formation of voids and gaps in root canals obturated with warm gutta-percha vertical compaction technique by using BeeFill. Twenty-four single-rooted teeth were collected and the root canals were prepared by using rotary files. All teeth were randomly allocated into three groups. Each group was obturated by using the BeeFill system in combination with Sealapex, RoekoSeal and 2Seal. Following preparation, all teeth were scanned with a micro-computed tomography (CT) scanner and a three-dimensional reconstruction of the obturated root canals was performed to analyze the volume of interface voids and gaps in the obturated teeth. It was concluded that none of the root canal-filled teeth were free of voids. Teeth obturated with RoekoSeal had the highest quality of obturation.

Gandolfi MG (2013)[71] analysed the interfacial volume of voids present in the obturated root canals as indirect index of sealing ability using the micro Computed Tomography. About eight teeth were prepared by using ProTaper rotary NiTi instruments. All the roots were filled by using Thermafil size 30 and AH Plus sealer and were immersed in 5mL Hank's Balanced Salt Solution at 37 °C to allow the sealers to set. Afterwards the teeth were analyzed using a micro-CT system. The analysis was performed using the software CT Analyser version 1.10.1.0 (Skyscan, Belgium). The percentage of voids and gaps in the filled root canals were also analyzed after a period of 1 week and 6 months. The results demonstrated good sealing ability by all the systems used in this study.

Samson Immanuel (2013)[72] evaluated the apical sealing ability of three different obturation techniques. A total of 120 extracted human permanent anterior maxillary and mandibular single rooted teeth were selected and divided into 3 groups based up on the method of obturation. After obturation of all the three groups, the teeth were immersed in 1% of aqueous methylene blue dye for a period of two weeks and then the samples was subjected to spectrophotometric analysis. GroupI (Thermafil) obturation technique showed minimum mean apical dye penetration when compared to Group II (ObturaII) and Group III (Lateral Condensation). Lateral Condensation shows the maximum mean apical dye penetration among all three groups. There was no significant difference in the apical dye penetration between the Lateral Condensation and Obtura II technique.

Samadi.F *et al* (2014)[73] evaluated the Percentage of Guttapercha filled Area using microscopic analysis of the cross sections in the apical third of root canals when filled with Thermafill technique, Warm Vertical Condensation technique and Cold Lateral Compaction technique without sealers. Sixty single rooted extracted permanent teeth and divided it into 20 specimens of three groups. Group-I-Thermafill, GroupII-Warm Vertical Condensation,Group III-Cold Lateral Condensation obturation technique. After obturation, the teeth were cross-sectioned horizontally at 2-3 mm from apex and examined under a stereomicroscope under magnification 50x.This study supported Thermafill which obturation produced significantly higher Percentage of Gutta percha Filled Area [PGFA] than Warm Vertical Condensation technique or Cold Lateral Condensation technique.

A.Keles (2014)[74] evaluated the percentage volumes of filling materials and voids in oval-shaped canals. The root canals were filled with either Cold Lateral Compaction or Warm Vertical Compaction technique using the micro Computed Tomography. About 24 single rooted maxillary premolar teeth with oval canals were selected for this study and the root canals were prepared and assigned to two groups with 12 samples each. Each specimen was scanned using a micro-CT at an isotropic resolution of 12.5 µm. The percentage volumes of the root filling materials and the voids were calculated. It was concluded that, no root fillings were void free. Warm Vertical Compaction produced a significantly greater volume of gutta percha and a significantly lower percentage of voids than those achieved with Cold Lateral Compaction.

Saeed Moradi (2014)[75] determined the quality of root canal obturation performed by the undergraduate dental students at the Dental School, University of Mashhad, Iran. In this study, a random 200 records of patients who received endodontic treatment at the Dental School, University of Mashhad between 2009 and 2010 was investigated. The quality of root canal, density and length of root filling were the parameters that were evaluated in this study. About 38% of teeth fulfilled the criteria of an acceptable root canal filling. Adequate length and density of root filling was found in 73% and 66% of teeth respectively. There was a significant difference between the maxillary and mandibular teeth according to the quality, length and density of root filling and the frequency of root canals with an acceptable filling was significantly greater in the anterior teeth than in molars.

Juliane Nhata *et al* (2014)[76] evaluated the quality and bond strength of three root filling techniques -Lateral Compaction, Continuous Wave of Condensation and Tagger Hybrid technique [THT]) using micro-Computed Tomography (CT) images and push-out tests, respectively. In this *invitro* study, thirty mandibular incisors were prepared and randomly divided into three groups. Lateral Condensation Technique (LCT), continuous Wave of Condensation Technique (CWCT), and THT. All the specimens were filled with Gutta-percha (GP) cones and AH Plus sealer. Five specimens of each group were randomly chosen for micro-CT analysis and all of them were sectioned into 1 mm slices and subjected to push-out tests. Micro-CT analysis revealed less amount of empty spaces when GP was heated within the root canals in Continous Wave of Condensation and Tagger Hybrid technique when compared to the Lateral Compaction technique. It was concluded from this study that, Lateral Compaction was associated with more voids than the other techniques.

Ruchi Gupta *et al* (2015)[77] compared the quality of three different root canal obturation techniques: Lateral Compaction, Thermafil and Calamus by using Cone Beam Computed Tomography. A total of 30 central incisors were selected and biomechanical preparation was done by Reciproc file no 25.The teeth were then divided into 3 groups of 10 teeth each according to the obturation technique i.e. Calamus, Thermafil and Lateral Compaction. Cone Beam Computed Tomography was used to measure the filling area and voids at coronal, middle and apical third of the root canal after obturation by different techniques. Data was statistically analysed by One-Way Anova and multiple comparison of Tukey HSD tests. The results showed that the maximum amount of obturating material was observed in Calamus group followed by Thermafil and Lateral Compaction. Minimum voids were seen in obturation by Calamus technique.

Anna Kierklo (2015)[78] evaluated the adaptation and quality of root fillings achieved by the Lateral Condensation, Vertical Condensation, Thermafil, Ultrafil and Obtura II techniques. Seventy-five straight and curved root canals of extracted human teeth were prepared according to the crown-down technique using 3% sodium hypochlorite. Apical patency was verified with a size 15 K-file and five groups of 15 root canals were allocated for obturation by the different obturation techniques. The teeth were then radiographed for overall material adaptation and extrusion of filling material. There were no significant differences in the radiographic density and adaptation of obturating material to the canal walls. All thermoplastic obturation techniques demonstrated acceptable root canal fillings.

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MATERIALS AND ARMAMENTARIUM USED FOR EVALUATING HOMOGENEITY AND QUALITY OF OBTURATION.

- Human mandibular 1st premolar (n=120)
- Endodontic access bur (Dentsply Maillefer,Ballaigues, Switzerland)
- ISO size 15 K-Files (Dentsply Maillefer,Ballaigues, Switzerland)
- 17% EDTA (De smear, Anabond Stedman Pharma,India.)
- 2.5 % sodium hypochlorite (Nova Dental products Pvt Ltd, Mumbai, India)
- 27 gauge side vented needle (RC Twents, Prime Dental products pvt Ltd)
- Normal saline (Nice chemicals Pvt Ltd.,Delhi,India).
- Protaper rotary file system (Dentsply Maillefer,Ballaigues, Switzerland)
- Paper points (Dentsply, Mailleffer, Ballaigues Switzerland.)
- Lentulospiral (Dentsply, Mailleffer, Ballaigues, Switzerland.)
- AH plus sealer (Dentsply De Trey Gmbh, Konstanz, Germany)
- Cold plugger(Dentsply, Mailleffer, Ballaigues, Switzerland)
- Guttapercha points (Dentsply, Mailleffer, Ballaigues, Switzerland)(4% size 30)
- Gutta flow 2 (Coltene,Whaledent, Germany)
- Thermafill (Dentsply, Tulsa Dental Specialities-Tulsa)
- Beefill (VDW,GmbH,Bayerwaldstr,Munich , Germany).

EQUIPEMENT USED FOR THE ANALYSIS OF HOMOGENEITY AND QUALITY OF OBTURATION

- **CBCT SCANNER** - ORTHOPOX SG (Sirona Dental systems, Bensheim, Germany)
- **SOFTWARE ANALYSIS**-Galileos viewer (Version1.9) (Sirona Dental systems, Bensheim,Germany)

TABLE 1 COMPOSITION OF AH PLUS SEALER:

EPOXIDE PASTE	AMIDE PASTE
▪ Diepoxide ▪ Calcium tungstate ▪ Zirconium oxide ▪ Aerosil ▪ Pigment	▪ 1-adamantane amine ▪ N,N'-dibenzyl-5-oxa -nonandiamine-1,9 ▪ TCD-Diamine ▪ Calcium tungstate ▪ Zirconium oxide ▪ Aerosil ▪ Silicone oil

COMPOSITION OF GUTTAFLOW 2:

- Polydimethylsiloxane particles
- Silicone.
- Paraffin oil.
- Platinum catalyst
- Zirconium dioxide
- Nano-silver
- Gutta-percha powder.

METHODOLOGY

COLLECTION OF SAMPLES

One twenty (120) lower first premolars which were extracted for orthodontic purpose were collected from the department of Oral and Maxillofacial Surgery, Rajas Dental College, Kavalkinaru. Teeth which had caries, restoration, apical resorption or had undergone previous endodontic treatment were excluded from this study. In order to standardize the samples for homogeneity, teeth which had acute curvatures, root canal anomalies and calcifications were excluded.

PREPARATION OF THE SAMPLES

All the collected teeth specimens were then washed thoroughly in running tap water for two minutes and was then immersed in 5.25% sodium hypochlorite solution(Sigma Aldrich, Germany) for a period of 24 hours in order to remove the organic debris such as the tissue remnants which were adherent to the root surface. Any calculus, present on the surface of the root was removed using a gracey curette (Hu-Friedy, Mfg. Co., LLC Chicago). The prepared samples were then stored in normal saline solution at 37ºC and at 95% humidity for a period of 15 days.

PREPARATION OF THE ROOT CANAL

Conventional access cavity was prepared using the Endo access bur (size-2,Dentsply Maillefer, Ballaigues, Switzerland) using a high speed airotor handpiece . A number 15 K- file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the root canal until the tip of the instrument was visible at the root apex. After which the working length was measured radiographically (bisecting angle technique) using Ingles method. From the obtained radiographic working length the actual working length

(WL) was calculated by subtracting 0.5 mm from the radiographic value for safety allowance.

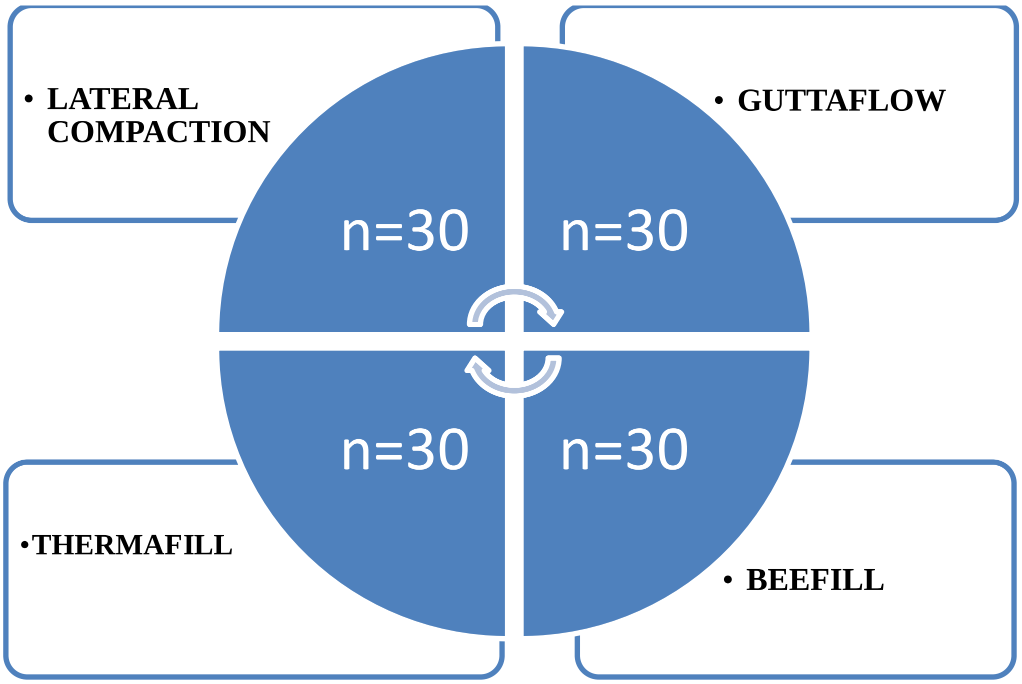
After establishing a straight line access, a smooth glide path was created using a number 15 K file. After which the canal was enlarged up to two sizes using a 25-K file. Then cleaning and shaping of the canal was continued using the Protaper universal rotary file system (Dentsply, Maillefer, Ballaigues, Switzerland) up to the size F3. About 2 ml of 2.5% sodium hypochlorite (Nova Dental products Pvt Ltd, Mumbai, India) was used for irrigation using a 27 gauge side vented needle (RC Twents, Prime Dental products pvt Ltd) in between each filing. For the removal of smear layer, 1 ml of 17% EDTA solution (De smear, Anabond Stedman Pharma, India) was used followed with intermittent rinsing of 2mL of 2.5% sodium hypochlorite solution. A final flush was done by using 4ml of normal saline solution. The prepared root canals were then dried with the appropriately sized paper points (Dentsply Maillefer, Ballaigues, Switzerland) and then the samples were randomly divided into four groups of 30 samples each.

SCANNING OF THE SPECIMENS USING CBCT

A preoperative CBCT imaging (Sirona Dental systems, Bensheim, Germany) was first performed for all the study samples. A CBCT scanner (ORTHOPHOS XG 3D, Sirona Dental systems, Bensheim, Germany) with a 3D cylinder volume of (8× 8 cm), a tube voltage of 90 kvp and a current of 5mA was used. The samples were then fixed in memory foam and positioned on the specimen stage after which the scanning was done. Each image had a resolution of 160 µm and the Field Of View (FOV) for each scan was 4cm and the voxel size was 0.4 mm.

By using the Galileo's viewer software (v 1.9) (Sirona Dental systems, Bensheim Germany) the images obtained by the scanner were reconstructed so as to show the 3-dimensional slices of the roots. The axial, coronal and sagittal view of the entire root canal was then recorded. Then the area of the prepared root canal in each slice was calculated from the linear measurements measured using the CBCT scanner. About 15mm of the total root length was taken into consideration for the evaluation of homogeneity and for the purpose of evaluating the quality of obturation. This 15mm root length having a slice thickness of 0.5 mm was viewed under, high resolution CBCT scanner. The volume (R) of the root canal in each slice was then calculated by multiplying the root canal area with the slice thickness (0.5 mm). The root length was then equally divided into 5mm segments at the coronal, middle and apical third and then the volume (R_c, R_m, R_a) of each segment was calculated separately.

TOTAL NO OF SAMPLES=120



OBTURATION OF THE ROOT CANAL

After the preoperative CBCT analysis, AH plus sealer(Dentsply,Maillefer Ballaigues, Switzerland) was mixed according to the manufacturer instructions and was coated along the walls of the prepared canals using a lentulospiral (No.3, Dentsply Maillefer, Ballaigues Switzerland) attached to a micromotor hand piece rotating at 300 rpm. The prepared samples were grouped into four groups with thirty samples each. The samples in group 1 were obturated using the Lateral Compaction technique, in group 2 the samples were obturated using Guttaflow, the samples in group 3 were obturated with Thermafill and in group 4 the samples were obturated with Beefill. All these procedures were carried out according to the manufacturer's instructions**.**

Group 1 -Cold Lateral condensation (CLC)

The 30 samples in group 1 were obturated using Lateral Condensation technique. This technique was done using a 30 size (0.04 taper) gutta percha (Dentsply, Maillefer, Ballaigues, Switzerland) as the master cone. The master cone was placed into the canal till the working length with tug back. Then 25, 20 and 15 sized finger spreaders (Dentsply,Maillefer, Ballaigues, Switzerland) were used to create spaces for Lateral Condensation of guttapercha and the root canal was filled with the appropriately sized accessory cones. The excess guttapercha at the orifice of the root canal was sheared off by using a heated ball burnisher.

Group 2 Guttaflow (GF)

The 30 samples in group 2 were obturated by using the cold free flow obturation technique. In this technique, GuttaFlow 2 (Coltene, Whaledent, Germany) was used as the obturating material. When the piston of the 5ml automix syringe was pressed, Guttaflow was mixed at the ratio of 4:1 and then it flowed from the tip of the applicator. The mixed Guttaflow, was then spread on the mixing pad. The master cone (size 30) (0.04 taper) (Dentsply, Maillefer, Ballaigues, Switzerland) was then coated with Guttaflow and inserted into the root canal. After the master cone was placed with tug back into the root canal, a heated hand plugger of size 30 (Dentsply, Maillefer, Ballaigues, Switzerland) was used to shear off the guttapercha leaving about 4mm at the apex. Then Guttaflow was then injected to back fill the root canal adequately (or) completely.

Group 3 Thermafill (TF)

The 30 samples in group 3 was obturated using Thermafill obturation technique. A size 30 Thermafill verifier (0.04 taper and 25 mm length) was used to check the diameter of the prepared root canal. After which a size 30 Thermafill cone was heated in the ThermaPrep plus oven (Tulsa Dental Products, OK, USA) according to the manufacturer's instructions. The heated Thermafill cone was then introduced into the canal and the excess guttapercha was sheared off using a heated size 60 hand plugger (Dentsply, Maillefer, Ballaigues, Switzerland)

Group 4 Beefill (BF)

The 30 samples in Group 4 were obturated using the Beefill obturating system. A master cone (size 30) (0.04 taper) was gently inserted into the root canal to about 0.5 mm short of the WL to prevent the extrusion of the heated guttapercha into the periapex. A heated size 30 plugger (Dentsply, Maillefer, Ballaigues, Switzerland) was used to shear the guttapercha points approximately 3 to 4 mm short of the apex. The Beefill obturating system was set at a temperature of 180ºC. Then the needle tip was introduced into the root canal 4mm short of the working length and then the heated guttapercha was slowly injected into the canal following which, the needle was withdrawn and the guttapercha was vertically compacted using a Machtou hand plugger, Size 0 (ISO 40) (VDW, Munich, Germany) according to the manufacturer's instructions. Back filling of the entire root canal was done by holding the needle against the apically compacted guttapercha. Then a Machtou hand plugger (VDW, Munich, Germany) of Size 3 (ISO 80) was used to compact the guttapercha at the canal orifice.

After obturation, all the access cavities were filled with Cavitemp and then stored at 37ºC and at 95% humidity for about 72 hours to aid in the complete setting of the sealers. Then a second CBCT scan was done in order to determine the volume of the obturated material at the coronal, middle and apical third of the obturated root canals. Approximately 15mm of the root length was taken into consideration for the CBCT analysis. This length of 15 mm is further divided into equal coronal, middle and apical segments. Each segment had a slice thickness 0.5mm. Hence each tooth was then scanned for a section of 30 slices to detect the presence or absence of voids.

The volume of the root canal in each slice was already calculated by multiplying the root canal area by the slice thickness (0.5mm) during the preoperative CBCT analysis(R). Thus the total volume of the predetermined (15mm) root length was calculated by adding up the values obtained for the total 30 slices. In the study specimens where void was seen, the inner area of the void was calculated using the linear measurements obtained using the Galileos viewer software and this value was multiplied by the slice thickness in order to calculate the Volume of the Void (V).The volume of the obturated material was calculated using the formula (R-V).

The Volume Percentage of the voids in the obturated root canal (VP) was calculated by using the formula, (R-V) ×100/R where, R is the volume of the root canal space and V is the volume of the void space. The homogeneity of obturation was evaluated by estimating the prevalence of the voids at the coronal, middle and apical segments of the obturated root canals. The technical quality of the root fillings was then assessed by the parameters specified by the, **Quality Assurance Guidelines, American Association of Endodontists** in the year 1987.

TABLE 2 Quality of the root fillings assessed by the parameters specified by the, **Quality Assurance Guidelines, American Association of Endodontists** (1987).

0-Consistently dense, radiopaque filling in all the three segments (apical, middle and coronal) were gutta-percha is well adapted to the canal outline
1-Minimal variation in the density throughout with some evidence of small voids (< 0.5 mm) or instrument marks <10% of the total filling.
2- Moth-eaten appearance or voids (< 0.5 mm) present in the apical third, and/or which is evident throughout the filling.
3- Voids (> 0.5 mm but < 1.0 mm) in the apical third, and/or which is evident throughout the filling
4- Voids (> 1.0 mm) in the apical third and or evident which is present throughout the filling.

TABLE 3 Criteria for the extrusion of the material through the apical foramen

0 - No sealer or gutta-percha present beyond the working length.
1- Sealer or gutta-percha present beyond working length but not at the radiographic apex
2- Sealer and/or gutta-percha present at the radiographic apex.
3- Sealer and/or gutta-percha beyond the radiographic apex

The values were then tabulated and analysed using an appropriate statistical method.

FIG 1.1
COLLECTION OF SAMPLES

FIG 1.2
ARRANGED SAMPLES

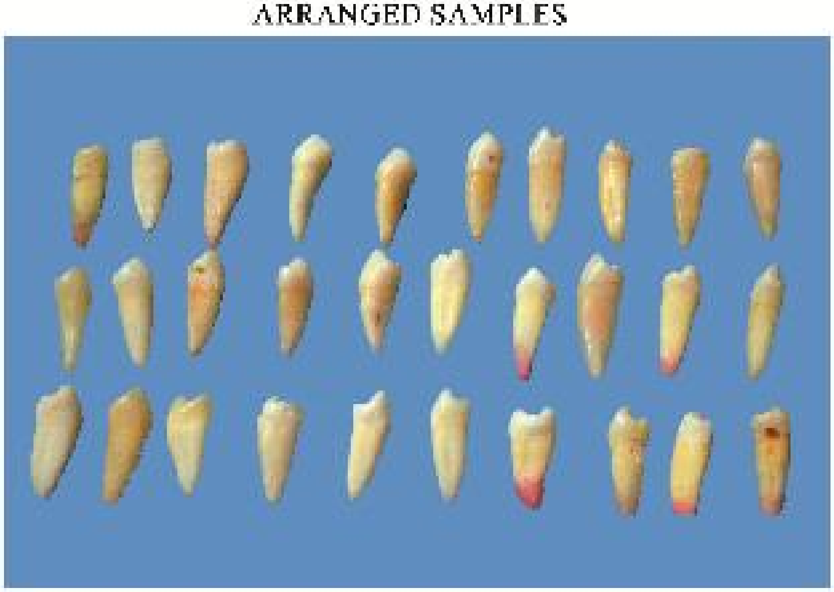


FIG1.3
MATERIALS USED FOR CLEANING AND SHAPING

FIG 1.4
IRRIGANTS

FIG 2.1
ACCESS CAVITY PREPARATION

FIG 2.2
PROTAPER ROTARY SYSTEM

FIG 2.3
CLEANING & SHAPING USING PROTAPER ROTARY SYSTEM

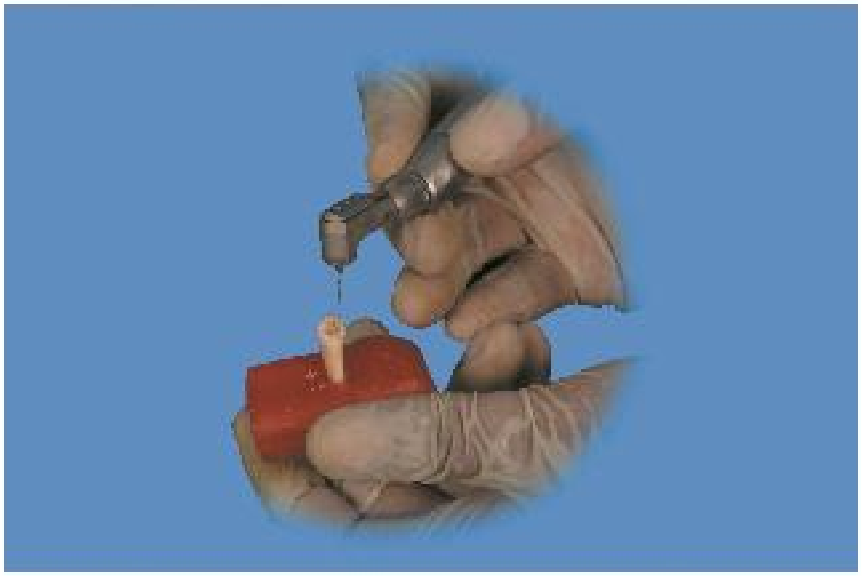


FIG 2.4
AH PLUS SEALER

FIG 2.5
GUTTAPERCHA POINTS

FIG 3.1
SELECTION OF MASTER CONE

FIG 3.2
OBTURATION USING LATERAL COMPACTION TECHNIQUE

FIG 3.3
CORONAL SEAL USING CAVITEMP

FIG 4.1
GUTTAFLOW 2

FIG 4.2
OBTURATION USING GUTTAFLOW

FIG 5.1
THERMAPREP PLUS OVEN

FIG 5.2
THERMAFIL OBTURATORS

FIG 5.3
OBTURATION WITH THERMAFIL OBTURATORS

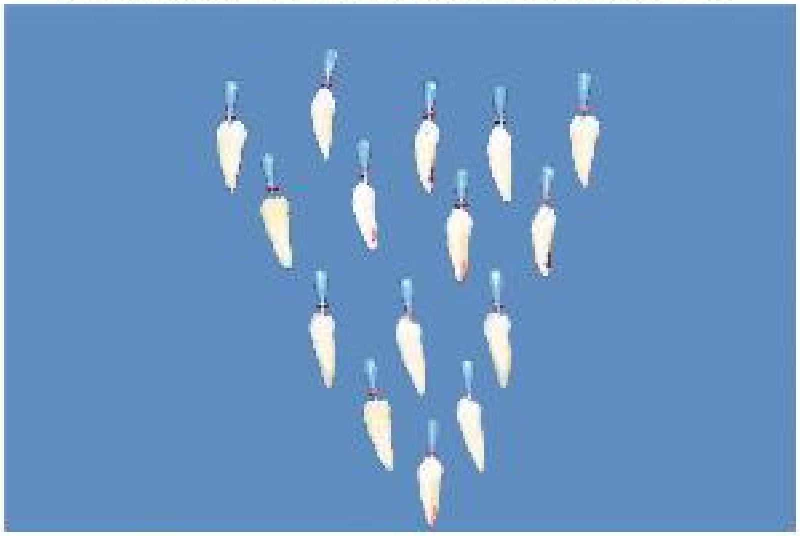


FIG 6.1
BEEFILL 2 IN 1 OBTURATING SYSTEMS

FIG 6.2
OBTURATION USING BEEFILL

FIG 6.3
VERTICAL COMPACTION USING MACHTOU PLUGGER

FIG 7
ARRANGED SAMPLES FOR POST OPERATIVE CBCT ANALYSIS

FIG 7.1
MOUNTED SAMPLES ON SPECIMEN STAGE OF CBCT MACHINE

FIG 7.2
CBCT MACHINE

FIG 8.1
PREOPERATIVE CBCT IMAGE OF GROUP 1
CORONAL SEGMENT

FIG 8.2
POST-OPERATIVE CBCT IMAGE OF GROUP 1
CORONAL SEGMENT

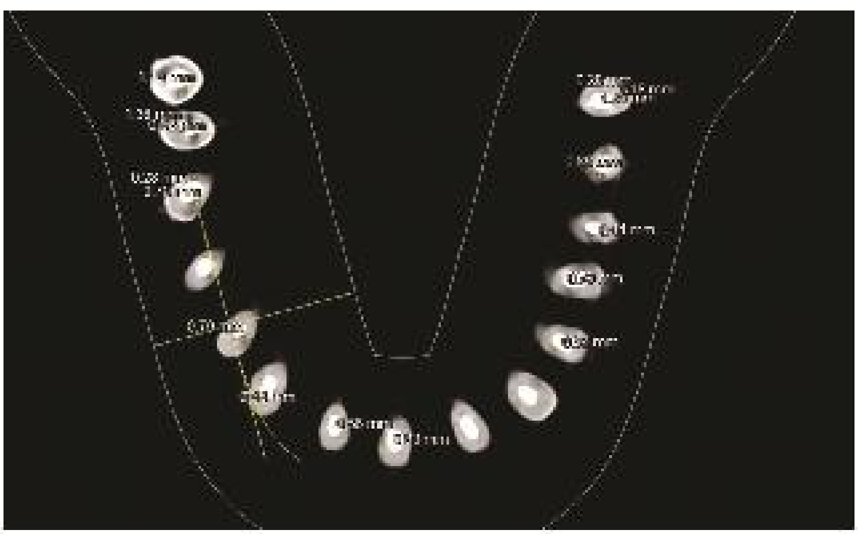


FIG 8.3
PREOPERATIVE CBCT IMAGE OF GROUP I
MIDDLE SEGMENT

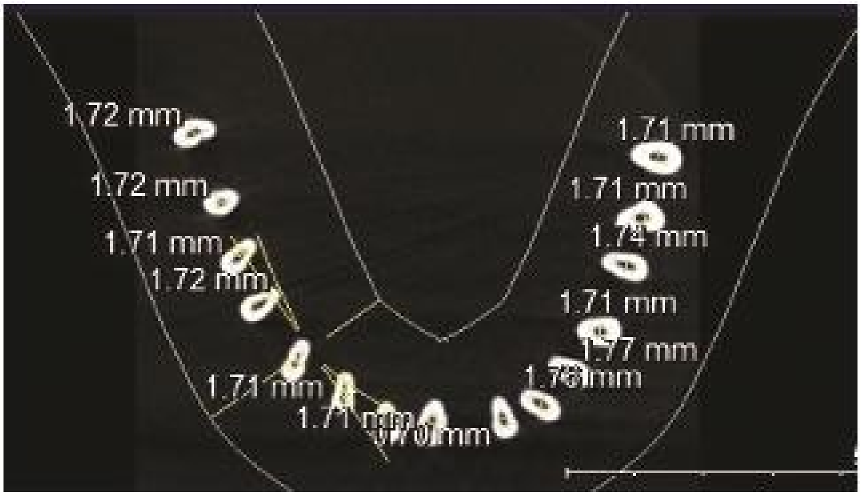


FIG 8.4
POST OPERATIVE CBCT IMAGE OF GROUP I
MIDDLE SEGMENT

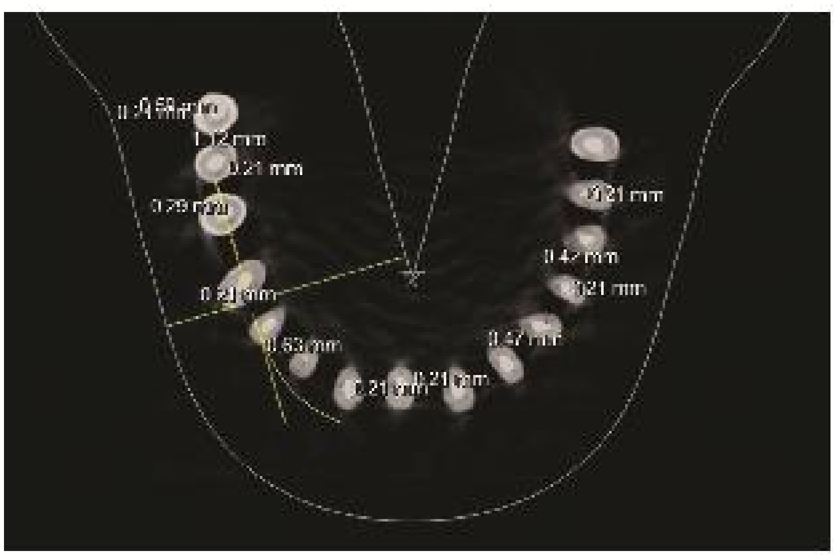


FIG 8.5
PRE OPERATIVE CBCT IMAGE GROUP I
APICAL SEGMENT

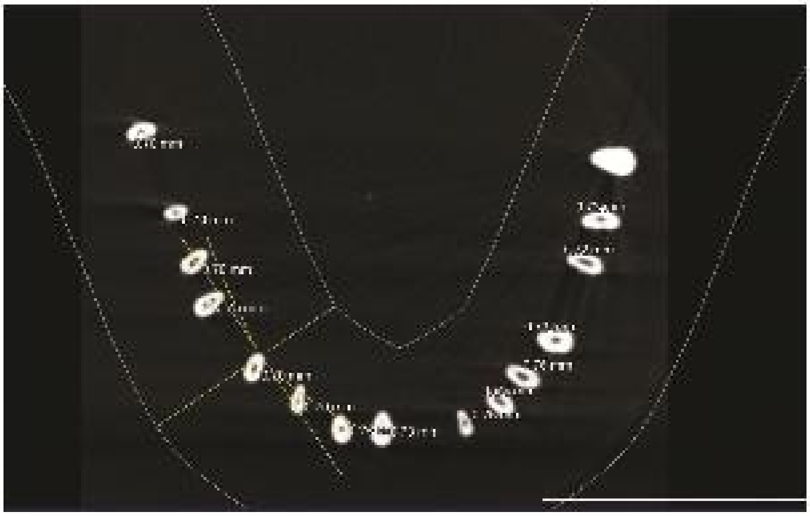


FIG 8.6
POST OPERATIVE CBCT IMAGE OF GROUP I
APICAL SEGMENT

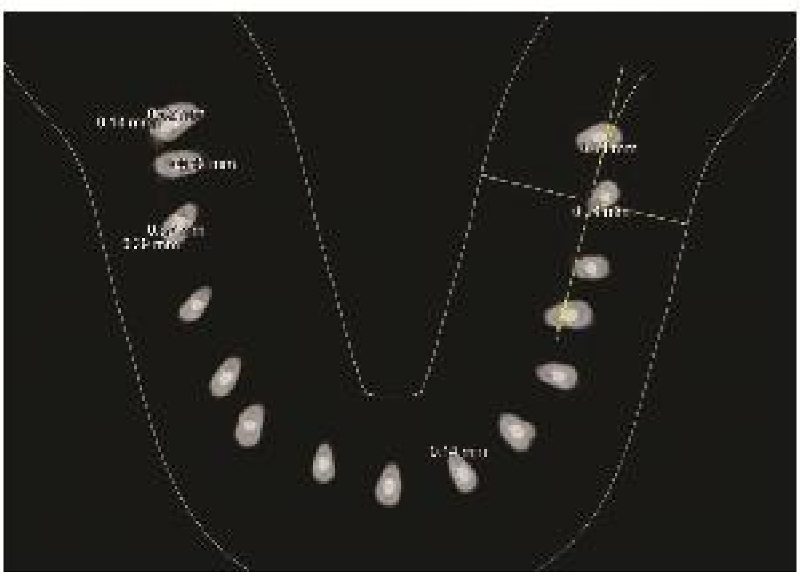


FIG 8.7
PREOPERATIVE CBCT IMAGE OF GROUP 2
CORONAL SEGMENT

FIG 8.8
POSTOPERATIVE CBCT IMAGE OF GROUP 2
CORONAL SEGMENT

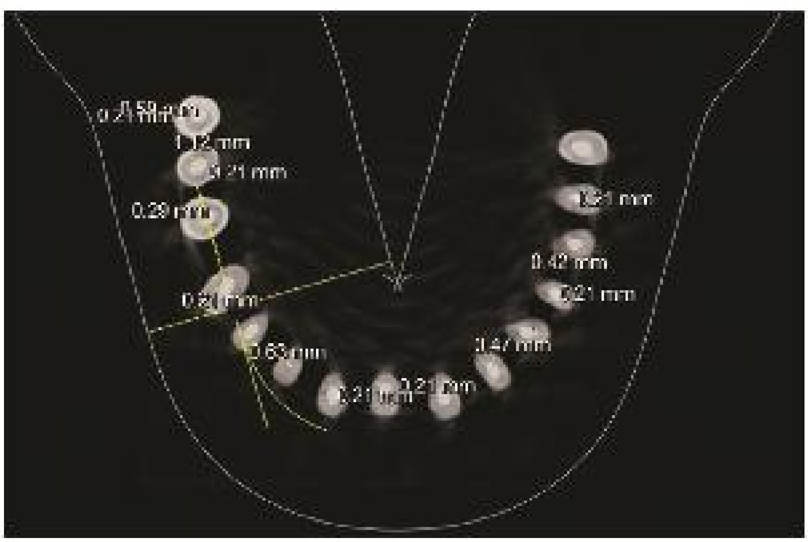


FIG 8.9
PREOPERATIVE CBCT IMAGE OF GROUP 2
MIDDLE SEGMENT

FIG 8.10
POST OPERATIVE CBCT IMAGE OF GROUP 2
MIDDLE SEGMENT

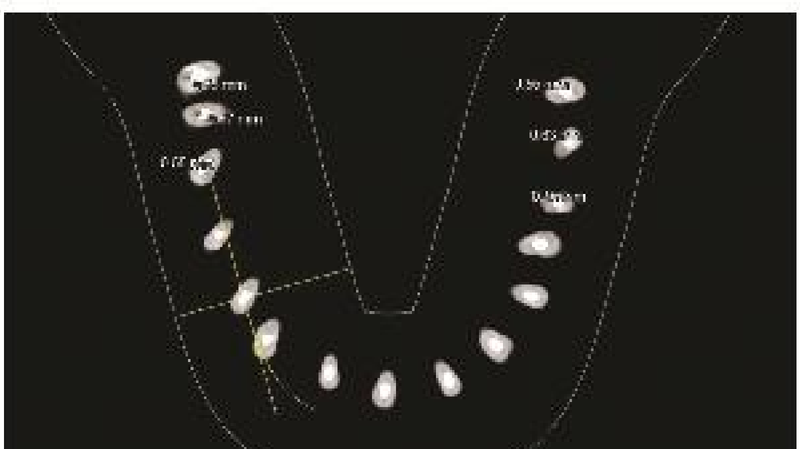


FIG 8.11
PREOPERATIVE CBCT IMAGE OF GROUP 2
APICAL SEGMENT

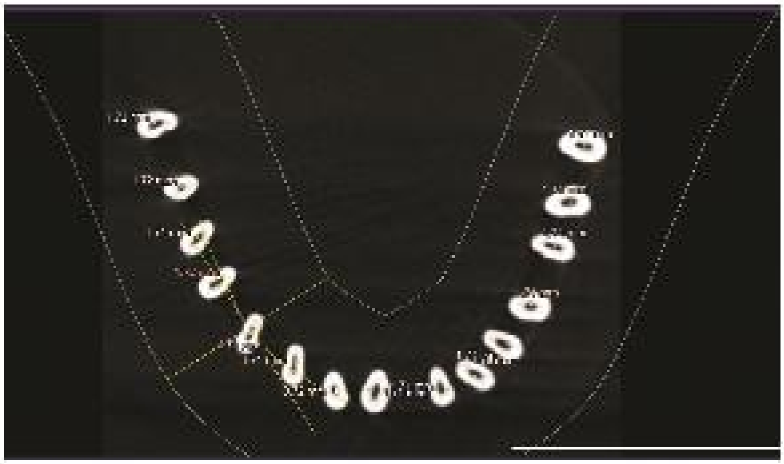


FIG 8.12
POST OPERATIVE CBCT IMAGE OF GROUP 2
APICAL SEGMENT

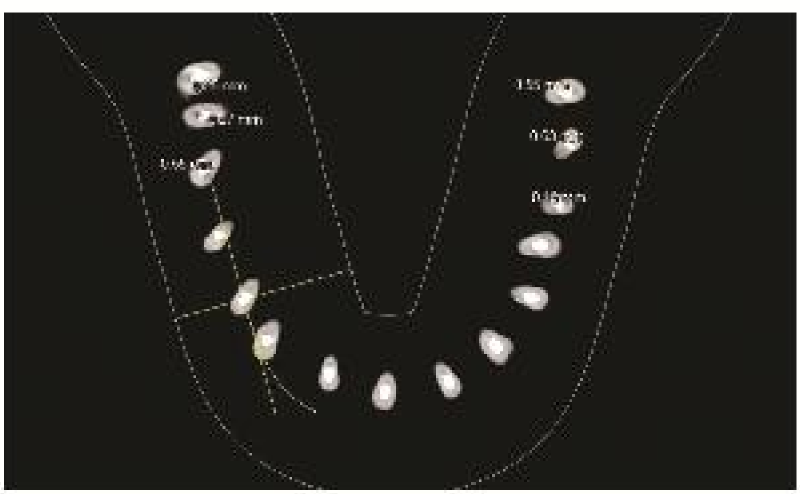


FIG 8.13
PREOPERATIVE CBCT IMAGE OF GROUP 3
CORONAL SEGMENT

FIG 8.14
POSTOPERATIVE CBCT IMAGE OF GROUP 3
CORONAL SEGMENT

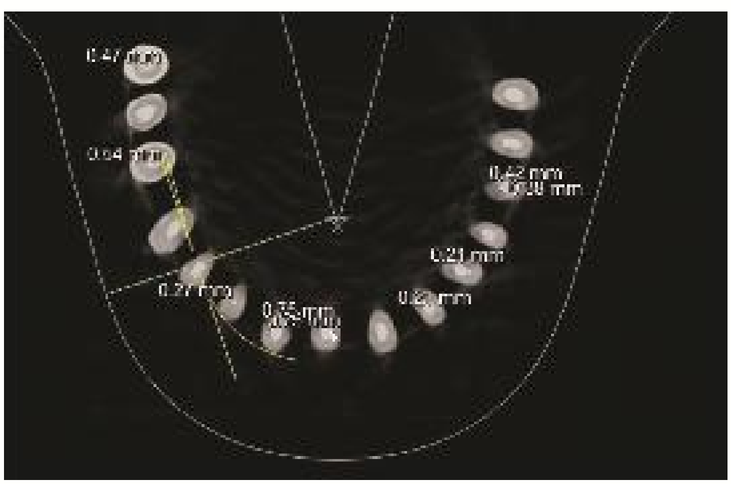


FIG 8.15
PREOPERATIVE CBCT IMAGE OF GROUP 3
MIDDLE SEGMENT

FIG 8.16
POST OPERATIVE CBCT IMAGE OF GROUP 3
MIDDLE SEGMENT

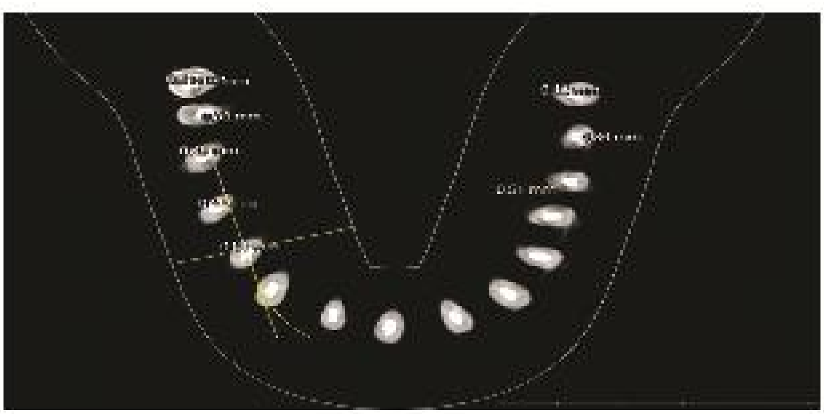


FIG 8.17
PREOPERATIVE CBCT IMAGE OF GROUP 3
APICAL SEGMENT

FIG 8.18
POST OPERATIVE CBCT IMAGE OF GROUP 3
APICAL SEGMENT.

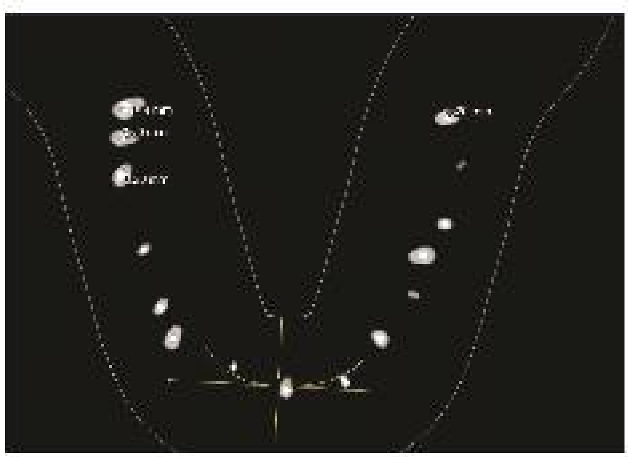


FIG 8.19
PREOPERATIVE CBCT IMAGES OF GROUP 4
CORONAL SEGMENT

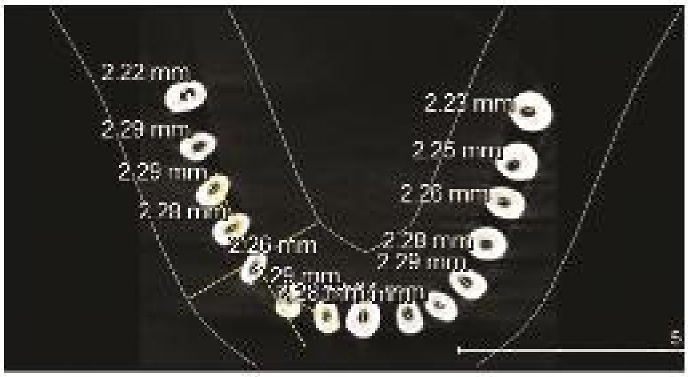


FIG 8.20
POST OPERATIVE CBCT IMAGE OF GROUP 4
CORONAL SEGMENT

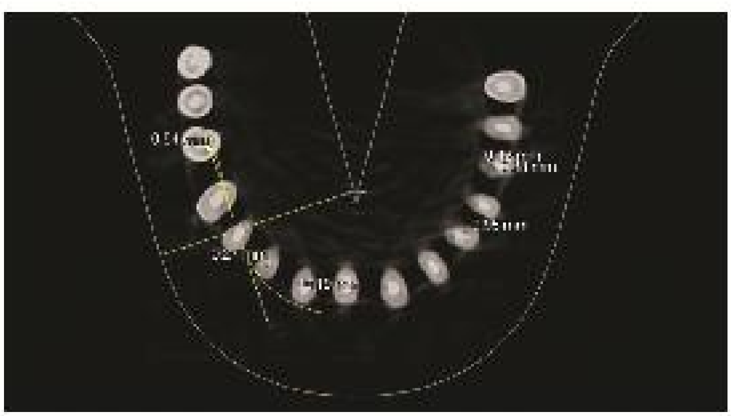


FIG 8.21
PREOPERATIVE CBCT IMAGE OF GROUP 4
MIDDLE SEGMENT

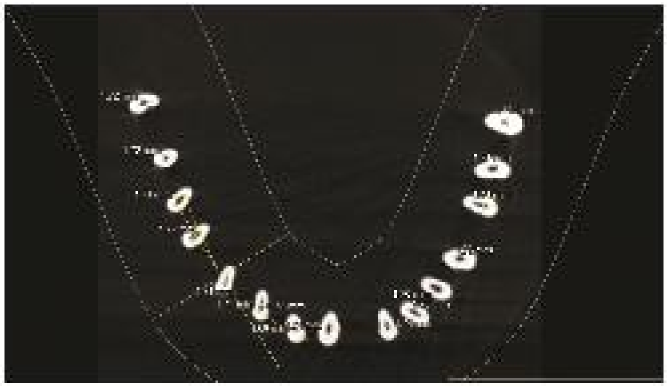


FIG 8.22
POST OPERATIVE CBCT IMAGES OF GROUP 4
MIDDLE SEGMENT

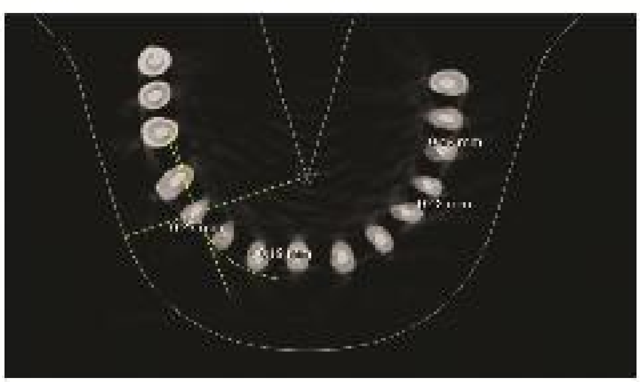


FIG 8.23
PREOPERATIVE CBCT IMAGES OF GROUP 4
APICAL SEGMENT

FIG 8.24
POSTOPERATIVE CBCT IMAGES OF GROUP 4
APICAL SEGMENT

FIG 8.25
EXTRUSION OF GUTTAPERCHA SEEN IN
LATERAL COMPACTION GROUP

STATISTICAL ANALYSIS

The data entry was done with Microsoft office excel spread sheet. Statistical analysis was performed using SPSS version 17.0 software. Both descriptive and analytical statistics was performed.

Descriptive statistics

Measures of central tendency i.e, Mean and Measures of Dispersion i.e, Standard deviation was calculated for all the parameters.

Inferential Statistics

To compare the mean difference of all the parameter between the 4 groups of obturation techniques Analysis of Variance (ANOVA) was calculated and to find out the exact significance among those 4 groups of obturation techniques a multiple comparison post-hoc using Bonferroni test was performed. P value < 0.05 was considered as significant. P value <0.01 is considered as highly significant.

Significance level interpretation

NS-Not significant

*-Significant

**-Highly significant

RESULTS

Using the linear measurements obtained from the CBCT analysis the void volume, obturated material volume and the volume percentage of the coronal, middle and apical segments were determined. The quality of obturation as well as the presence of extrusion was also calculated using the scoring method.

Table 1shows the intergroup comparison of the coronal total volume percentage of all groups. In which the highest mean value was of the Beefill group (96.7973%) and lowest was of Lateral Compaction group (87.4840%).The results were not statistically significant as P value was 0.076.

Table 2 shows the intergroup comparison of the middle total volume percentage of all groups in which the mean value was highest in the Beefill group (99.7947 %). The results also shows that the mean value was lowest in the Lateral Compaction group (93.5467%). The F value for the middle total volume percentage was 1.654 and the P value was 0 .187 which was considered to be statistically insignificant.

Table 3 shows the intergroup comparison of the apical total volume percentage of all groups. According to this table, the mean apical total volume percentage was higher for the Beefill group (97.8633%) but for the Lateral Condensation group it was of the lowest value 92.0820%. The F value for the apical total volume percentage was 0.518 and the P value was .671.The P value was considered to be statistically insignificant.

Table 4 shows the intergroup comparison of the overall total volume percentage of all groups. For Beefill the value was highest - 97.9273%. The mean overall total volume percentage of the Lateral Compaction group was the lowest- 88.9407%. The F value was 7.459 and P <0.05 which was statistically significant.

Table 5 shows the intergroup comparison of the overall quality of obturation of the four groups. The result shows that for Beefill the quality of obturation was better whereas

Lateral Condensation shows poor quality of obturation. The F value was 2.398 and the P value was 0.078 which was statistically insignificant.

Table 6 shows the one way ANOVA of variance for the presence of extrusion among the four groups. The results shows that extrusion was present in the Lateral Compaction group and the mean value was 3.07 and for Beefill the mean value was 1.033 and the P value is 0.002 which was statistically significant. The F value was 5.768.

Table 7 shows the multiple comparison of the total coronal volume percentage of the obturated material in the four groups using the Post Hoc test-Bonferroni test. When Lateral Condensation is compared with Guttaflow, Thermafill and Beefill the values are statistically insignificant. When Guttaflow is compared with Lateral Compaction, Thermafill and Beefill the values are statistically insignificant. When Thermafill is compared with Lateral Compaction, Guttaflow and Beefill the values are statistically insignificant. When Beefill is compared with Lateral Compaction, Guttaflow and Thermafill the values are statistically insignificant.

Table 8 shows the multiple comparison of the total middle volume percentage of the obturated material in the four groups using the Post Hoc test-Bonferroni test. The results shows that the values are statistically insignificant when compared between Lateral Condensation, Guttaflow, Thermafill and Beefill. Even when Guttaflow was compared with the other groups or when Thermafill was compared with the other groups the values remain statistically insignificant.

Table 9 shows the multiple comparison of the total apical volume percentage of the obturated material in the four groups using the Post Hoc test-Bonferroni test. When Lateral Condensation is compared with Guttaflow, Thermafill and Beefill the values are statistically insignificant. When Guttaflow is compared with Lateral Compaction, Thermafill and Beefill the values are statistically insignificant. There was no difference in the results even when Thermafill and Beefill were compared with the other groups.

Table 10 shows the multiple comparison for the presence of extrusion between the four groups using the Post Hoc test-Bonferroni test. When Lateral Condensation is compared with Guttaflow and Thermafill the values are statistically insignificant. But when Lateral Condensation is compared with Beefill the values are highly significant,where the $P<0.001$. When Guttaflow is compared with Lateral Compaction, Thermafill and Beefill the values are statistically insignificant. When Thermafill is compared with Lateral Compaction, Guttaflow and Beefill the values are statistically insignificant. When Beefill is compared with Lateral Compaction the values are significant whereas with Guttaflow and Thermafill the values are statistically insignificant.

Table 11 shows the multiple comparison of the overall volume percentage of the obturated material in the four groups using the Post Hoc test-Bonferroni test. When Lateral Condensation is compared with the other groups, the values are statistically insignificant. The results also show that when Guttaflow or Thermafill or Beefill was compared with the other groups the values were statistically insignificant.

Graph 1 shows the inter group comparison of the total coronal volume percentage between the four different groups. The different obturation techniques are plotted along the x-axis and the volume percentage is plotted along the y-axis.

Graph 2 shows the inter group comparison of the total middle volume percentage between the four different groups. The different obturation techniques are plotted along the x-axis and the volume percentage is plotted along the y-axis.

Graph 3 shows the inter group comparison of the total apical volume percentage between the four different groups. The different obturation techniques are plotted along the x-axis and the volume percentage is plotted along the y-axis.

Graph 4 shows the inter group comparison of the overall total volume percentage between the four different groups. The different obturation techniques are plotted along the x-axis and the volume percentage is plotted along the y-axis.

Graph 5 shows the inter group comparison of the overall quality of obturation between the four different groups. The different obturation techniques are plotted along the x-axis and the quality scoring values are plotted along the y-axis.

Graph 6 shows the inter group comparison of extrusion for the obturated material between the four different groups. The different obturation techniques are plotted along the x-axis and the scoring values are plotted along the y-axis.

There is no statistical significant difference in the total coronal volume percentage of the different groups when compared with the control group (i,e) Lateral Compaction(Table 4).Similarly there is no statistical significance in the total middle volume percentage and apical volume percentage of the different groups when compared with the control group (i,e) Lateral Compaction (Table 5,6).But there is statistical significant differences in the overall volume percentage of the obturated material among the Lateral Compaction group and Beefill group ($P<0.01$) (Table 7).

While evaluating for determining the quality of obturation there is no statistically significant difference in the results between the groups when compared with the control group.(Table 8).While evaluating for the presence of extrusion there is statistically significant difference in the results between Lateral Compaction and Beefill. ($p<0.005$) (Table9).

TABLE 1

DESCRIPTIVE ANALYSIS (ANOVA) OF CORONAL TOTAL VOLUME PERCENTAGE OF FOUR GROUPS.

Parameter	Group	Mean	Std.Deviation	F test value	P Value
Coronal TVP	Lateral condensation	87.4840	6.97062	2.412	.076
	Guttaflow	85.0713	6.5465		
	Thermafill	92.7267	7.06104		
	Beefill	96.7973	6.07722		

GRAPH 1

COMPARISON OF CORONAL TOTAL VOLUME PERCENTAGE BETWEEN THE

FOUR DIFFERENT GROUPS

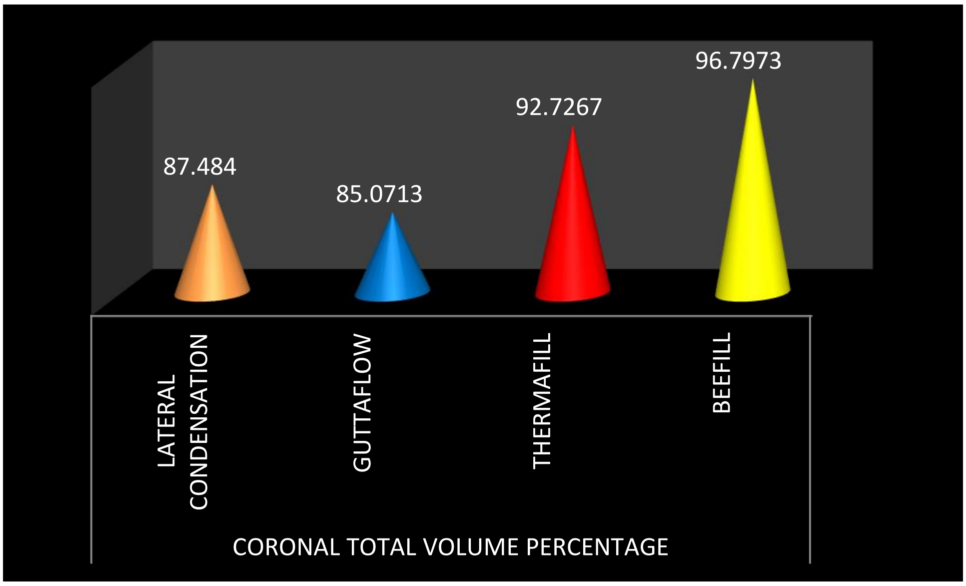


TABLE 2

DESCRIPTIVE ANALYSIS (ANOVA) OF MIDDLE TOTAL VOLUME PERCENTAGE OF FOUR GROUPS

Parameter	Group	Mean	Std.Deviation	F test value	P Value
Middle TVP	Lateral condensation	93.5467	10.98999	1.654	.187
	Guttaflow	97.5420	9.51979		
	Thermafill	95.1560	7.75179		
	Beefill	99.7947	.42569		

GRAPH 2

COMPARISON OF MIDDLE TOTAL VOLUME PERCENTAGE BETWEEN THE FOUR DIFFERENT GROUPS

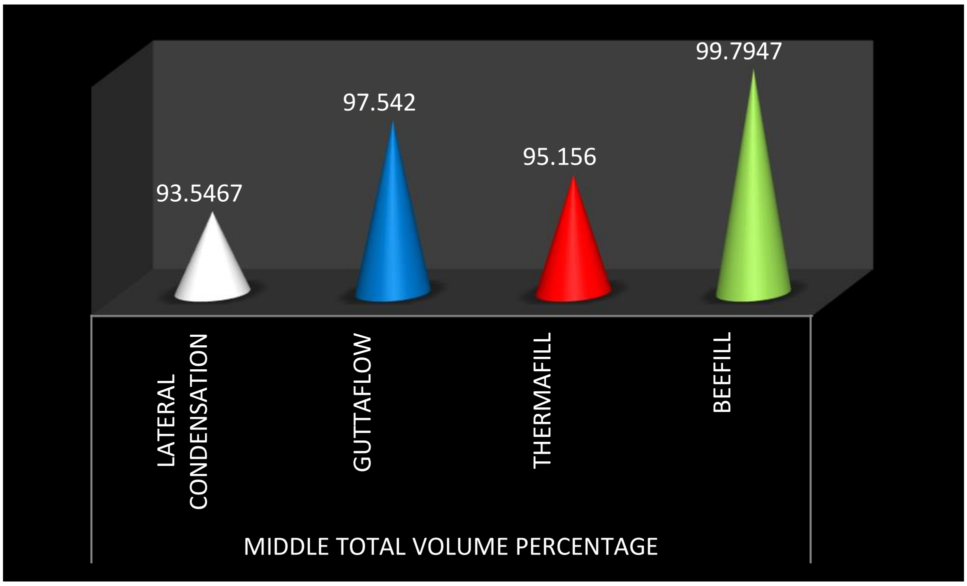


TABLE 3

DESCRIPTIVE ANALYSIS (ANOVA) OF APICAL TOTAL VOLUME PERCENTAGE OF FOUR GROUPS

Parameter	Group	Mean	Std.Deviation	F test value	P Value
Apical TVP	Lateral condensation	92.0820	18.77557	.518	.671
	Guttaflow	95.8467	12.73007		
	Thermafill	96.6500	12.97449		
	Beefill	97.8633	6.09249		

GRAPH 3

COMPARISON OF APICAL TOTAL VOLUME PERCENTAGE BETWEEN FOUR DIFFERENT GROUPS

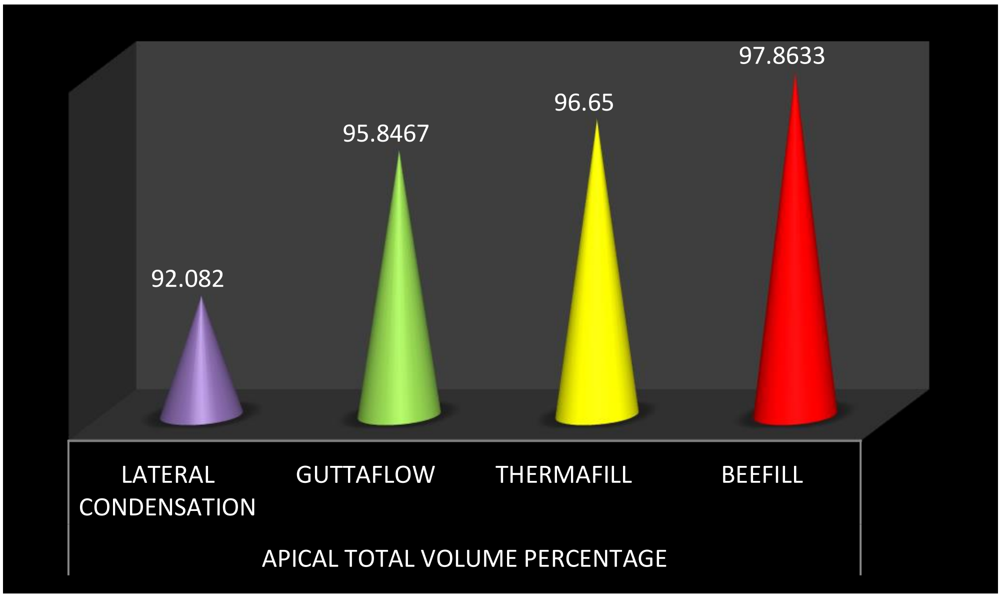


TABLE 4

DESCRIPTIVE ANALYSIS (ANOVA) OF OVERALL TOTAL VOLUME PERCENTAGE OF FOUR GROUPS

Parameter	Group	Mean	Std.Deviation	F test value	P Value
Overall TVP	Lateral condensation	88.9407	5.91149	7.459	0.000**
	Guttaflow	93.0113	6.42955		
	Thermafill	94.1753	4.59541		
	Beefill	97.9273	3.57144		

GRAPH 4

COMPARISON OF OVERALL TOTAL VOLUME PERCENTAGE BETWEEN THE FOUR DIFFERENT GROUPS

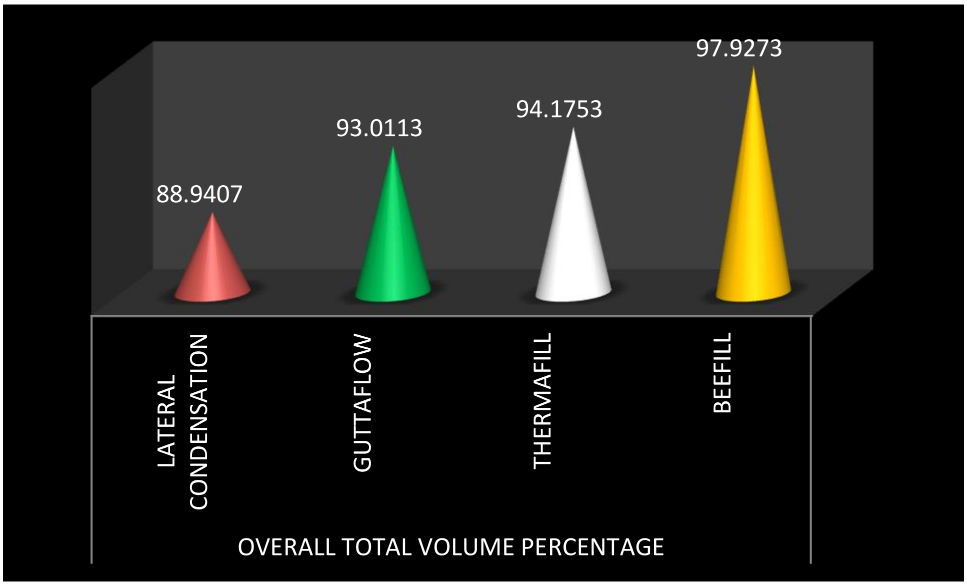


TABLE 5

DESCRIPTIVE ANALYSIS (ANOVA) OF OVERALL QUALITY OF OBTURATION OF FOUR GROUPS

Parameter	Group	Mean	Std.Deviation	F test value	P Value
Overall quality	Lateral condensation	1.60	.986	2.398	.078
	Guttaflow	1.20	1.146		
	Thermafill	1.00	1.000		
	Beefill	.67	.724		

GRAPH 5

COMPARISON OF THE OVERALL QUALITY OF OBTURATION BETWEEN THE FOUR DIFFERENT GROUPS

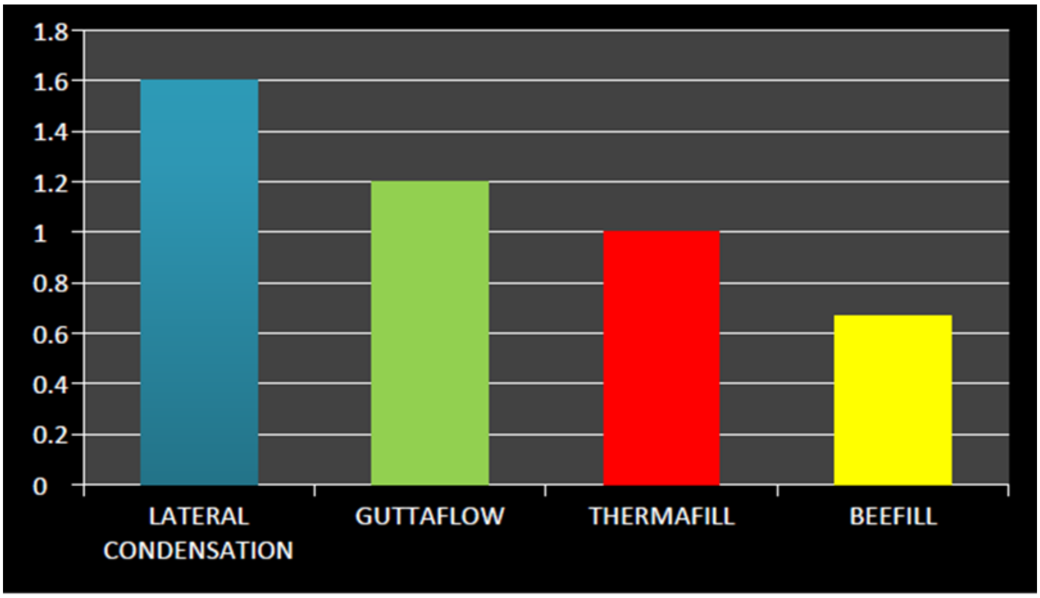


TABLE 6

DESCRIPTIVE ANALYSIS (ANOVA) OF OVERALL EXTRUSION BETWEEN OF FOUR GROUPS

Parameter	Group	Mean	Std.Deviation	F test value	P Value
Overall TVP	Lateral condensation	3.07	1.223	5.768	0.002**
	Guttaflow	1.87	1.767		
	Thermafill	1.87	1.506		
	Beefill	.93	1.033		

GRAPH 6

COMPARISON OF EXTRUSION OF GUTTAPERCHA BETWEEN THE FOUR DIFFERENT GROUPS

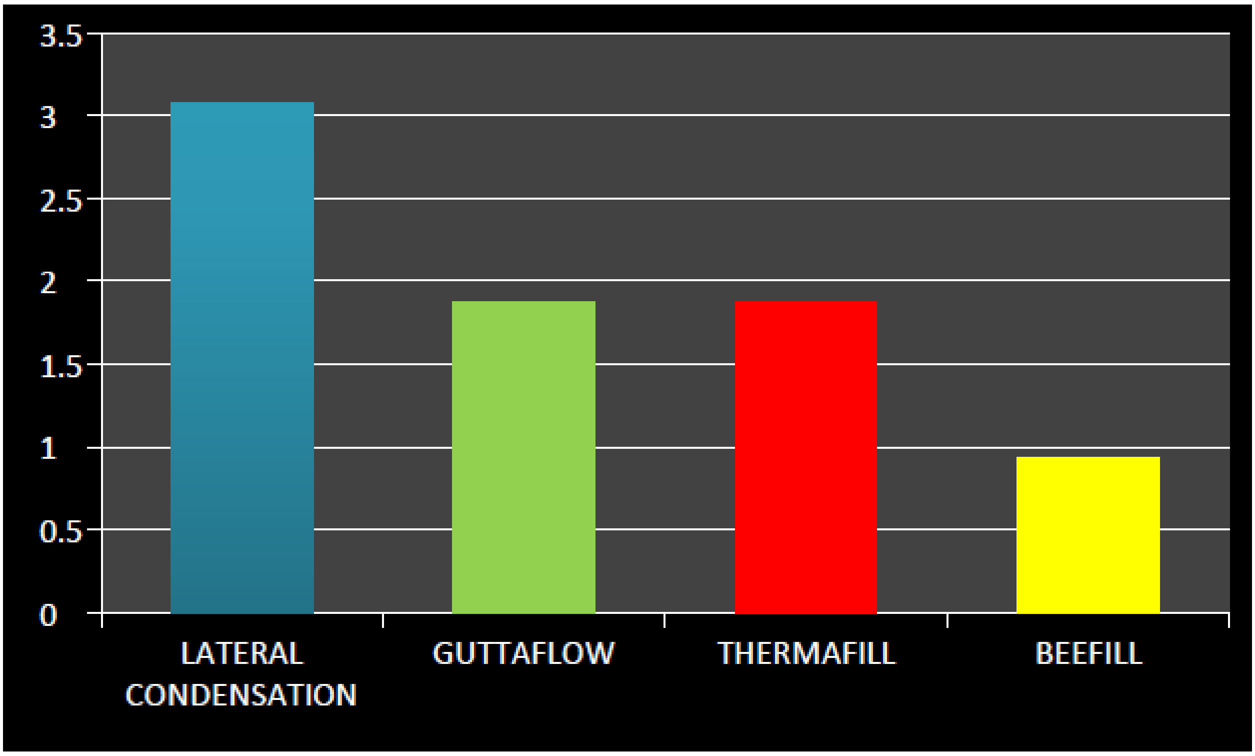


TABLE 7

MULTIPLE COMPARISON OF THE TOTAL CORONAL VOLUME PERCENTAGE OF THE OBTURATED MATERIAL IN FOUR GROUPS USING POST HOC TEST-BONFERRONI TEST

Dependant Variable	(I)Group	(J)Group	Mean diff	Mean diff	Sig.	95%confidence Interval	
						Lower Bound	Upper bound
Coronal TVP	Lat. condensation	Guttaflow	2.41267	4.7952	1.000	-10.703	15.5286
		Thermafill	-5.2426	4.7952	1.000	-18.358	7.8733
		Beefill	-9.3133	4.7952	.343	-22.429	3.8026
	Guttaflow	Lat.condensation	-2.4126	4.7952	1.000	-15.528	10.7033
		Thermafill	-7.6555	4.7952	.696	-20.771	5.4606
		Beefill	- 11.726	4.7952	.106	-24.841	1.3899
	Thermafill	Lat.condensation	5.24267	4.7952	1.000	-7.8733	18.3585
		Guttaflow	7.65533	4.7952	.696	-5.4606	20.7713
		Beefill	-4.0706	4.7952	1.000	-17.186	9.0453
	Beefill	Lat.condensation	9.31333	4.7952	.343	-3.8026	22.4293
		Guttaflow	11.7260	4.7952	.106	-1.3899	24.8419
		Thermafill	4.07067	4.7952	1.000	-9.0453	17.1866

TABLE 8

MULTIPLE COMPARISON OF THE TOTAL MIDDLE VOLUME PERCENTAGE OF THE OBTURATED MATERIAL IN FOUR GROUPS USING POST HOC TEST-BONFERRONI TEST

Dependant Variable	(I)Group	(J)Group	Mean diff	Mean diff	Sig.	95%confidence Interval	
						Lower Bound	Upper Bound
Middle TVP	Lateral condensation	Guttaflow	-3.99533	3.00931	1.000	-12.2265	4.2458
		Thermafill	-1.60933	3.00931	1.000	-9.8405	6.6218
		Beefill	-6.24800	3.00931	.255	-14.4791	1.9831
	Guttaflow	Lat.condensation	3.99533	3.00931	1.000	-4.2358	12.2260
		Thermafill	2.38600	3.00931	1.000	-5.8451	10.6111
		Beefill	-2.25267	3.00931	1.000	-10.4838	5.9785
	Thermafill	Lat.condensation	1.60933	3.00931	1.000	-6.6218	9.8405
		Guttaflow	-2.38600	3.00931	.696	-10.6171	5.8451
		Beefill	4.63867	3.00931	.773	-12.8698	9.0453
	Beefill	Lat.condensation	6.24800	3.00931	.255	-1.9831	14.4791
		Guttaflow	2.25267	3.00931	1.000	-5.9785	10.4838
		Thermafill	4.63867	3.00931	.773	-3.5925	12.8698

TABLE 9

MULTIPLE COMPARISON OF THE TOTAL APICAL VOLUME PERCENTAGE OF THE OBTURATED MATERIAL IN FOUR GROUPS USING POST HOC TEST-BONFERRONI TEST

Dependent Variable	(I)Group	(J)Group	Mean Difference	Std. error	Sig	95%confidence Interval	
						Lower Bound	Upper Bound
Apical TVP	**Lateral Condensation**	**Guttaflow**	-3.76467	4.8990	1.000	-17.1688	9.6354
		Thermafill	-4.56800	4.8990	1.000	-17.9681	8.8321
		Beefill	-5.78133	4.8990	1.000	-19.1814	7.6188
	Guttaflow	**Lat.condensation**	3.76467	4.8990	1.000	-9.6354	17.1648
		Thermafill	-.80333	4.8990	1.000	-14.2034	12.5968
		Beefill	-2.01667	4.8990	1.000	-15.4168	11.3834
	Thermafill	**Lat.condensation**	4.56800	4.8990	1.000	-8.8321	17.9681
		Guttaflow	-.80333	4.8990	1.000	-12.5968	14.2034
		Beefill	-1.21333	4.8990	1.000	-14.6134	912.188
	Beefill	**Lat.condensation**	5.78133	4.8990	1.000	-7.6188	19.1814
		Guttaflow	2.01667	4.8990	1.000	-11.3834	15.4168
		Thermafill	1.21333	4.8990	1.000	-12.1869	14.6134

TABLE 10

MULTIPLE COMPARISON OF THE OVERALL VOLUME PERCENTAGE OF THE OBTURATED MATERIAL IN FOUR GROUPS USING POST HOC TEST-BONFERRONI TEST

Dependent Variable	(I)Group	(J)Group	Mean difference	Std.error	Sig.	95%confidence Interval	
						Lower bound	Upperbound
Overall TVP	Lateral Condensation	Guttaflow	-4.07067	1.91623	.228	-9.3120	1.1706
		Thermafill	-5.23467	1.91623	.050	-10.4760	.0066
		Beefill	-8.89667	1.91623	.000**	-14.228	-3.7454
	Guttaflow	Lat.Condensation	4.07067	1.91623	.228	1.1706	9.3120
		Thermafill	-1.16400	1.91623	1.000	-6.4053	4.0773
		Beefill	-4.91600	1.91623	.078	-10.1573	.3253
	Thermafill	Lat. condensation	5.23467	1.91623	.050	-0066	10.4760
		Guttaflow	1.16400	1.91623	1.000	-4.0773	6.4053
		Beefill	-3.75200	1.91623	.331	8.9933	1.4893
	Beefill	Lat.condensation	8.98667	1.91623	.000**	3.7454	14.2280
		Guttaflow	4.91600	1.91623	.078	-.3253	10.1573
		Thermafill	3.75200	1.91623	.331	-1.4893	8.9933

TABLE 11

MULTIPLE COMPARISON OF THE EXTRUSION OF THE OBTURATED MATERIAL IN FOUR GROUPS USING POST HOC TEST-BONFERRONI TEST (According to the AAE, Quality Assurance Guidelines in 1987)

Dependent Variable	**(I)Group**	**(J)Group**	**Mean difference**	**Std.error**	**Sig.**	**95%confidence Interval**	
						Lower bound	**Upperbound**
Extrusion	**Lateral Condensation**	Guttaflow	1.200	.515	.140	-.21	2.61
		Thermafill	1.200	.515	.140	-.21	2.61
		Beefill	2.133	.515	.001**	.73	3.54
	Guttaflow	Lat.Condensation	-1.200	.515	.140	-2.61	.21
		Thermafill	.000	.515	1.000	-1.41	1.41
		Beefill	.933	.515	.451	- . 47	2.34
	Thermafill	Lat. condensation	-1.200	.515	.140	-2.61	.21
		Guttaflow	.000	.515	1.000	-1.41	1.41
		Beefill	.933	.515	.451	-.47	2.34
	Beefill	Lat.condensation	-2.133*	.515	.001	-3.54	-.73
		Guttaflow	-.933	.515	.451	-2.34	.47
		Thermafill	-.933	.515	.451	-2.34	.47

TABLE 12

MULTIPLE COMPARISON OF THE QUALITY OF THE OBTURATED MATERIAL IN FOUR GROUPS USING POST HOC TEST-BONFERRONI TEST (According to the AAE, Quality Assurance Guidelines in 1987)

Dependent Variable	(I)Group	(J)Group	Mean difference	Std. error	Sig.	95%confidenceInterval	
						Lowerbound	Upperbound
Quality	Lateral Condensation	Guttaflow	.400	.356	1.000	-.57	1.37
		Thermafill	.600	.356	.587	-.37	1.57
		Beefill	.933	.356	.068	-.04	1.91
	Guttaflow	Lat.condensation	-.400	.356	1.000	-1.37	.57
		Thermafill	.200	.356	1.000	-.77	1.17
		Beefill	.533	.356	.841	-.44	1.51
	Thermafill	Lat.condensation	-.600	.356	.587	-1.57	.37
		Guttaflow	-.200	.356	1.000	-1.17	.77
		Beefill	.333	.356	1.000	-.64	1.31
	Beefill	Lat.condensation	-.933	.356	.068	-1.91	.04
		Guttaflow	-.533	.356	.841	-1.51	0.44
		Thermafill	-.333	.356	1.000	-1.31	0.64

The three dimensional obturation of the root canal system helps to seal all the portals of microbial entry into the root canal space leading to secondary infection. Endodontic treatment failures mainly occur due to the inadequate obturation of the root canal space. Hence, the quality of the obturation determines the long term success of the endodontically treated tooth. Yu Hong Liang determined the association between the quality of the root canal filling and the formation of periapical lesions. The outcome of root canal treatment was said to be improved when the root canal filling is 0–2 mm from the apex and when there is no voids present in the complete obturation[62].Y.Boucher *et al* concluded that the teeth with acceptable root fillings were associated with a lower prevalence of periapical pathology[79]. According to Aqrabawi, the success rate of teeth treated with Lateral Compaction as well as with Warm Vertical Compaction does not differ except in teeth with periapical lesions[80]. On the contrary Brian M.Gillean *et al* concluded that the odds for the healing of apical periodontitis increases with both adequate root canal treatment and adequate restorative treatment. Although, treatment failures may also be expected with adequate root filling-inadequate coronal restoration and inadequate root filling–adequate coronal restoration, there is no significant difference in the level of healing between these combinations[81].

In this present study 120 lower first premolars with single root canals were selected so as to increase the significance of this study. The samples were then grouped into four groups of 30 samples each. This helps in the inter group comparisons as well as in the intra group comparisons for the presence of voids in the obturated root canals. The working length for the study was standardized at 15 mm of which 5mm each of the coronal, middle and apical segments were taken into consideration. In order to reduce the variability in the results all the root canals were prepared by the same operator using a standard cleaning and shaping protocol(crown down technique)

In this study, cleaning and shaping was performed by the crown down technique using the protaper rotary system. Nickel titanium rotary instruments such as Protaper have a modified cross-sectional design that resembles a K-File configuration instead of the U-shape which is common to many other rotary instruments. Rotary instruments having this geometry are seen to cut dentin more effectively and hence they may reduce the torsional loads[82]. Consequently, Protaper incorporates varying taper within one file, ranging from 3.5% to 19%. The modified guiding tip allows one to follow the canal better and the variable tip diameter allow the files specific cutting action in defined areas within the canal, without causing stress on the instrument in other sections[82]. Root canal instrumentation should result in an adequately tapered canal to allow for effective irrigation and a tight and impervious obturation. Hence, this can be accomplished with the use of Protaper NiTi rotary system for cleaning and shaping.

According to F. Foschi *et al*, Protaper produced a clean and debris-free dentin surface in the coronal and middle thirds but in their study they were unable to produce dentin surfaces free from smear layer as well as free of debris in the apical third region[83]. The presence of deep grooves and depression on the dentin walls in the apical third may well explain for the presence of less-instrumented areas. The preparation with protaper also helps to use spreaders and pluggers with 0.50-mm tips during the obturation of root canals. According to Shuping.G, cleaning and shaping with rotary nickel titanium instruments resulted in the reduced bacterial count[84].

Studies done by Gaurav sharma *et al* have shown that the smear layer can serve as an avenue for the ingress of microorganisms and also it can act as a source for the growth and activity of viable bacteria, which remain entrapped in the dentinal tubules[85]. Paula Amaral *et al* proved that the absence of a smear layer plays a significant role in the apical seal produced by the various obturation techniques[86]. White *et al* observed more effective results for smear layer removal when EDTA was used as the final irrigant[87].Vivacqua-Gomes *et al* observed lower infiltration levels as well as a better apical seal for teeth irrigated with EDTA[88]. These findings support the advantage of removing the smear layer and indicate that EDTA is an efficient root canal irrigant in this regard. EDTA also chemically softens the root canal dentin and dissolves the smear layer thereby increasing the dentinal permeability[89]. Although, the efficacy of EDTA in softening the root dentin has been debated, almost all the manufacturers of rotary nickel titanium instruments recommend their use as a lubricant during root canal preparation. So a final irrigation of the root canal with 15–17% EDTA solution helps to dissolve the smear layer[89]. Hence, in order to remove the smear layer, the root canals were irrigated with 2.5% sodium hypochlorite and17% EDTA solution intermittently in this study.

During and after instrumentation, the irrigants facilitate the removal of the microorganisms, tissue remnants and dentin chips from the root canal space through a flushing mechanism. Irrigants also prevents the packing of the hard and soft tissues in the apical root canal and also the extrusion of infected material into the periapical area. The most widely used endodontic irrigant is 0.5% to 6.0% sodium hypochlorite (NaOCl). It has a strong bactericidal activity and it also aids in dissolving vital and necrotic organic tissues[90,91]. NaOCl ionizes in the presence of water into Na and the hypochlorite ion (OCl) thereby establishing an equilibrium with hypochlorous acid (HOCl). At acidic and neutral pH, chlorine exists predominantly as hypochlorous acid HOCl, whereas at pH of 9 and above hypochlorite ion (OCl) predominates[92]. Hence the hypochlorous acid is responsible for the antibacterial activity of the irrigant. Hypochloric acid disrupts several vital functions of the microbial cell, resulting in cell death[93]. However, NaOCl solution does not exert any effect on the inorganic components present in the smear layer.

Sodium hypochlorite which is used in this study, helps to dissolve the organic and inorganic debris present in the root canal. In addition, it has a strong antimicrobial activity and actively kills bacteria and yeasts when introduced into the root canal space. Gomes B.P.F.A *et al* concluded that the ability of sodium hypochlorite to eliminate E.faecalis depends upon its concenteration[94.]. According to Craig.J although 0.5% NaOCl removed majority of the pulpal remnants and predentin from the un instrumented surfaces, it left some remnants on the root surface[95].According to Becking A.G, sodium hypochlorite is an irritant to the periapical tissues, especially at high concentrations but at low concentrations it can be used as a potent root canal irrigant[96].

As complete sealing of the root canal space is one of the most essential criteria in the obturation of the root canal system, root canal sealers are used along with the core material to obtain a fluid tight seal. According to Tronstad *et al* a complete radicular seal is as important as the coronal seal to maintain a proper periodontal health[97]. Studies by Schafer and Zandbiglari have proved that the conventional zinc oxide eugenol and calcium hydroxide based root canal sealers do not provide an adequate radicular seal[98]. So in order to improve the sealing properties, AH series of sealers were developed before 50 years. AH Plus is a mixture of epoxy-amines and is produced as a result of improvement in the AH -26 sealer. This sealer is used frequently as a control material for research purpose[99]. Hence, AH plus sealer was used as the root canal sealer in this study.

AH plus can be used along with guttapercha in vertical as well as lateral compaction techniques. AH plus sealer has low contraction and solubility in comparison to ZOE-based and calcium hydroxide based root canal sealers[100]. The sealing ability of AH plus sealer is controversial as it does not binds with the guttapercha. Bergmans. L *et al* have concluded that the use of adhesive resin sealers have the potential to reduce the rate of leakage and reinfection in the root canals[101]. But, S. Bouillaguet *et al* concluded that none of the currently available root canal sealers fully prevented fluid flow[102]. AH plus sealer is proved to be biocompactible and hence it can be used in adjunct with any of the obturation techniques and it also helps to provide an impervious fluid tight seal[103].

A preoperative CBCT analysis was done to evaluate the volume of the entire root canal space of all the study samples. CBCT is used as the diagnostic tool in this study because it is a non-invasive diagnostic method in which the entire root canal space can be evaluated in a single scan. The radiographic beam makes one rotation around the patient’s head and reconstructs millions of two-dimensional scans into one three-dimensional object[104]. This not only provides for a more detailed 2D object but also allows the viewer to rotate the 3D object and see around anatomical landmarks that cannot not be seen using conventional dental radiograph. Consistent with the advanced CBCT technology, CBCT analysis provides high-resolution images with both qualitative and quantitative analysis of the tooth and the obturated root canal space. The results obtained using CBCT are rapid and can be reproduced and it can also be compared with the histological findings.

Other diagnostic techniques like CT and microscopic evaluation of the root canal space are destructive as they cause the loss of tooth structure[105]. Also, in such techniques artifacts are produced due to the interference caused by the various root canal filling materials. Xing Liang *et al* compared the image quality and visibility of the anatomical structures in the mandible between five Cone Beam Computed Tomography (CBCT) scanners and one Multi-Slice CT (MSCT) system and concluded that CBCT image quality is comparable or even superior to MSCT due to the low radiation dose and high-resolution imaging[106].

After obturation of the prepared samples by using the four different obturation techniques, the homogeneity and the quality of the obturation was evaluated using CBCT for all the four groups. Homogeneity means that the root canal filling is a well compacted, uniform mass, without the presence of voids. A well condensed root canal filling should be free of voids in the coronal, middle and apical segments. In this study, the presence or absence of voids was compared among the four different groups. A CBCT scanner of voxel size 0.4 mm and a resolution of 160 µm was used for this study. This enables us to evaluate the presence of voids even in very thin root slices (0.5mm) at the coronal, middle or apical segments of the samples.

The prevalence of internal void is less relevant from a clinical point of view because, they provide an unfavourable environment for the bacteria that remain in the root canal system[107]. On the contrary, external voids are more important in determining the clinical success of the endodontically treated teeth. These voids are caused due to unsuccessful adaptation of the filling materials due to air entrapment between the filling materials and the root dentin. When such voids are present, the potential risk for microleakage is likely to be increased[107]. These voids also serve as a reservoir, where the pathogenic microorganisms can survive. Ng *et al* found that a root filling with no voids and a root filling extending to 2 mm within the radiographic apex along with a satisfactory coronal restoration were found to significantly improve the outcome of primary root canal treatment. It was also found that the peripheral gaps along the dentin-sealer or core material-sealer interfaces may jeopardize the outcome of root canal treatment[24]. This is because they may act as a pathway which allows for the sealer dissolution and also for the passage of microorganisms through the filled root canal and into the periradicular space. Furthermore, if residual microorganisms remain trapped within the dentinal tubules after treatment, the peripheral gaps may act as channels through which the microorganisms can gain access into the root canals[24].

The volume of the root canal before obturation was calculated from the linear measurements obtained after scanning the specimens with the CBCT scanner. Then the volume of the voids was calculated for the coronal, middle and apical 5mm sections using the linear measurements obtained from the CBCT. Each 5mm sections (coronal, middle and apical) were further divided into 10 sections of 0.5mm each. Hiroshi Watanabe *et al* quoted in his article that CBCT can evaluate tiny isotropic cubes of about 0.1-0.4 mm as well[108].The presence of voids in the 0.5mm slices (coronal, middle and apical segments) were taken into consideration. Then the volume of the obturated material was calculated by subtracting the volume of the voids from the volume of the root canals. Then the volume percentage of the obturated material was calculated by using the formula VP = (R-V) ×100/R, Where R is the volume of the root canal and V is the void volume[51]. In the inter group comparison for the presence of voids it was seen that the Lateral Condensation technique had a greater number of voids followed by Thermafill, Guttaflow and finally by the Beefill obturation technique.

Kandaswamy.D *et al* compared Lateral Condensation technique, vertically compacted thermaplasticized gutta-percha technique and cold free-flow gutta–percha (Gutta Flow) obturation techniques. Volumetric analysis was done using spiral CT and he found that there was least volume percentage in the Lateral Compaction group[45].Anbu *et al* evaluated the volume percentage of the obturated material using the same formula as in this study and found that Cold Lateral Compaction showed the least volume percentage of the obturated material[51].

The results obtained after the sectioning of the root for measuring and calculating the percentage of the surface area of filling materials and the voids might not be accurate as some part of the filling material might be lost in the process and 2D techniques cannot be accurately applied to measure a 3D structure. On sectioning the root, the loss of tooth material might mimic voids. Radiographs give only two-dimensional interpretations and the time taken for fluid filtration and clearing techniques may be a concern but dye penetration studies do not correlate clinically and dye extraction studies evaluate only the apical third of the tooth. Other studies like, bacterial microleakage studies need long periods of observation and the quantification of the number of penetrating bacteria is very difficult. In micro-CT evaluation, the segmentation of closely related objects such as calcified dental hard tissues and root canal filling material is possible but *in vivo* application of micro-CT technique has various limitations like high radiation dosage and availability.

CBCT provides satisfactory information about linear distances within an anatomic volume[109,110]. Loubele *et al* compared the accuracy of CBCT and multi slice CT for linear jaw bone measurements and found that both methods were accurate when used to evaluate an *ex vivo* specimen[111]. Mischkowski *et al* determined the geometric accuracy of CBCT scans in comparison with a multi detector computed tomography (MDCT) scanner. Their results showed that the CBCT device provides satisfactory information about linear distances and volumes[112]. Voxels contain multiple scalar values (vector data), such as density, opacity, colour and volumetric flow rate. Thus, they are used extensively for the visualization and analysis of scientific and medical data. Volume pixels are used like building blocks to form a larger 3D object. Voxels do not contain specific information about their axis coordinates but they have some information about their relative location in relation to nearby voxels and are considered as a single point in the 3D space.

During CBCT imaging, single exposures are made at certain degree intervals providing projection images. These are similar to the lateral, oblique, anterio-posterior and posterio-anterior "cephalometric" radiographic images. The complete series of images are referred to as the projection data[35].The number of images comprising the projection data is called as the frame rate and it is variable. This depends up on the imaging system and also on the settings applied. Greater the frame rate for a given scan time, more is the collected data to construct the image. Unfortunately, even though the high frame rates improved the image quality they also increase the radiation dose to the patient.

Recent studies by using CBCT images detected voids in the root filling and incomplete removal of the filling material during endodontic retreatment[50,112]. Sogur *et al* concluded that the image quality of storage phosphor images was subjectively as good as conventional film images and superior to limited-volume CBCT images for the evaluation of both homogeneity and also for the length of root fillings in single-rooted teeth[113]. Huybrechts *et al* analyzed voids in root fillings using the intraoral analogue, intraoral digital and CBCT images[114]. Voids larger than 30 µm were detected by all imaging techniques[115]. Apical extrusion, underfilled or adequately filled root canals were also evaluated by the scoring method .J. L. Gutmann, W. P. Saunders, E. M. Saunders and L. Nguyen evaluated the quality of root canal fillings using the same scoring method[18].

In the present study Lateral Condensation was used because it is the most commonly tested and used technique, and it served as a standard with which other techniques could be compared[116-117]. The Cold Lateral Condensation technique showed a significantly higher percentage of voids when compared with the other techniques. This is in agreement with previous studies done by Kandaswamy.D *et al* where he concluded that the least volume of obturation was seen in the Lateral Compaction group[45].

In the Cold Lateral Condensation technique, the remainder of the canal was filled with accessory points which were then packed using a spreader leading to a greater risk of void creation between the accessory points in the middle and coronal thirds as opposed to the apical third. Even in our study an increased number of voids were present in the coronal as well as in the middle segments of the lateral compaction group. One study showed that the final filling in Cold Lateral Compaction group had the appearance of numerous guttapercha cones tightly pressed together and joined by frictional grip[1]. CBCT evaluation of the Lateral Compaction group in this study also showed the presence of voids between the accessory cones throughout the length of the root canal in CLC group. Compared to all the other groups in the Cold Lateral Compaction group voids were also present between the guttapercha cones and the root dentin. This group also showed an increase in the number and diameter of voids. Voids were present in all the segments (coronal, middle and apical) in the Cold Lateral Compaction group. According to Wu and Wesselink Lateral Compaction technique failed to fill the uninstrumented recesses in oval canals[118]. C. H. Chu, E. C. M. Lo and G. S. P. Cheung evaluated the outcome of root canal treatment using either Thermafil (TF) or Lateral Condensation (LC) as filling technique and concluded that using TF or LC in the filling of root canals did not result in significant difference in the clinical treatment outcome[119].

M.K. Wu, A. Kautakova and P. R. Wesselink determined the quality of cold and warm gutta-percha fillings in oval canals and concluded that the percentage of gutta-percha-filled canal area using warm GP was greater than that of the cold GP in oval canals[120]. Kenan Clinton and Van T. Himelhis compared Thermafil with Lateral Condensation for the ability of guttapercha to adapt to the walls of a root canal system and found that Thermafil was able to flow better into the lateral spaces and had fewer voids compared to the lateral compaction technique but it caused more extrusion from the apical foramen than in the lateral condensation group[121].

Guttaflow is a new root canal obturation material with better flow and sealing properties at room temperature.[122] Although Guttaflow is known to expand slightly while setting, gaps and voids were seen in this study. This might be due to the filling technique which was used. The use of a single-cone filling technique is often considered inferior to the more sophisticated 3D compaction techniques, because the volume of the sealer is high relative to the volume of the cone, which promotes void formation and reduces the quality of the seal[123]. According to Elayouti *et al* voids present in Guttaflow between the sealer and the root canal walls can lead to an increase in the coronal microleakage[124]. In this study, Guttaflow exhibited less percentage of voids and gaps in the root sections in the coronal and middle third than in the Cold Lateral Compaction and Thermafill group. This can also be attributed to the filling technique, because the manufacturers of Guttaflow recommend that it is to be dispensed first in the apical part of the root canal and then the master gutta-percha cone should be placed. This ensures the least amount of voids and gaps in the apical third in the Guttaflow group in this study.

Kandaswamy.D *et al* compared the laterally condensed gutta-percha, vertically compacted thermoplastized gutta-percha (E and Q Plus system) and cold free-flow gutta–percha (GuttaFlow) using spiral CT and concluded that cold free-flow obturation technique showed the highest volume of obturation. This was followed by the vertically condensed thermoplasticized technique and the least volume of obturation was observed in Cold Lateral Condensation technique[45].This is in accordance with the results obtained in this study regarding Cold Lateral Condensation but on the contrary, Beefill resulted in an increased volume of obturated material than Guttaflow.

In this study more voids were seen in the Lateral Compaction group than in the Guttaflow group and this results are in contrary to a study done by Kumar N.S *et al* who compared the sealing ability between the Cold Lateral Condensation, thermoplasticized gutta-percha, and flowable gutta-percha obturation technique under a stereomicroscope at 40x magnification and concluded that the flowable gutta-percha group showed the maximum number of voids which was significantly higher than that of the Lateral Condensation group[125].

Thermafill exhibited more volume percentage compared to Guttaflow and Lateral compaction group. But the results were statistically insignificant. Carrier based obturation techniques are prone to the exposure of the carriers during their insertion into the root canal. This can cause the formation of voids between the root filling material and the root canal walls[126]. Adhesion between the gutta-percha and the carrier material is therefore an important requirement to effectively obturate the root canal system. D. S. Clark and Deeb concluded that the stripping of gutta-percha from the carrier occurs in the middle and apical thirds of the root canal[127].

In this study voids were present in the coronal third as well as in the middle third in Thermafill group. Through and through voids extending from the coronal segment to the middle segment was not seen in this group but present in Lateral Compaction group. Regarding the apical segment, there was hardly any void present and even if they were present, they were very minute and clinically insignificant. Regarding the quality of root fillings in Thermafill two cases of under filling and one case of apical extrusion was reported by CBCT analysis in this study, but this result is statistically insignificant. Underfilling may occur due to the improper use of size verifier and extrusion may be due to the loss of apical stop. These errors can also be considered as operator related errors.

Warm Vertical Compaction by thermaplasticized guttapercha technique resulted in a more homogenous three dimensional obturation than the other three techniques used in this study. Regarding the quality of obturation, there were only two cases of apical extrusion among the 30 samples and this is statistically insignificant. Use of heat softened guttapercha resulted in a more homogenous mass with less voids and improved adaptation to the canal walls in Beefill obturation technique. Tamer Tasdemir obturated with single cone, Lateral Compaction and Beefill in canals treated with ProTaper or Mtwo rotary instruments and the results showed similar levels of sealing efficacy[128]. Erhan Ozhan *et al* evaluated the sealing ability of five different root canal filling techniques and conclude that Continuous Wave of Condensation gave superior results[129]. Vicente Faus-Llacer *et al* measured the percentage of root canal fillings in long oval canals obturated with thermoplasticized gutta-percha techniques Beefill and Thermafill. Both systems achieved high percentage of filled canal and also the percentages of voids in both groups were very low. No significant differences were found between the two groups[130]. These results are in accordance with this study in which, more percentage of obturated material as well as fewer voids were present in the Beefill group. Even the quality of obturation was superior in Beefill compared to the other groups.

It is important to obturate the whole length of root canal but since the presence of voids in the apical third is very important all the measurements were done separately for the apical third as well. Based on the results of the present study, voids were detected in all the samples. The highest overall VP of void was detected in CLC group which was followed by Thermafill, Guttaflow and Beefill. The highest volume of obturated material is seen in Beefill followed by Guttaflow, Thermafill and Lateral Compaction. Voids were present in the Lateral Compaction group in the coronal middle as well as in the apical segment. Where as in Guttaflow and Thermafill groups voids were present in the coronal and middle segments but the results were statistically insignificant.

Within the limitations of this study, it can be concluded that voids were present in all the groups.

1) Beefill group had the maximum overall volume percentage of the obturated material.
2) Lateral Compaction group showed the least overall volume percentage of the obturating material.
3) Beefill showed better homogeneity and quality of obturation followed by Thermafill, Guttaflow and Lateral Compaction techniques
4) Thermafill and Guttaflow showed relatively comparable results regarding the homogeneity and quality of obturation.
5) The maximum number and diameter of voids were present in the Lateral Compaction group.
6) Voids were present in the coronal, middle as well as in the apical segments in the Lateral Compaction group.
7) Regarding the quality of obturation the quality of obturation was poor in Lateral Compaction group whereas in the other groups it was comparatively better.

This *in vitro* study was done inorder to evaluate the homogeneity and the quality of obturation by means of Lateral Compaction, Guttaflow, Thermafill and Beefill by using Cone Beam Computed Tomography

All the one twenty (120) specimens were washed thoroughly in running tap water for two minutes and were then immersed in 5.25% sodium hypochlorite solution for a period of 24 hours in order to remove the organic debris such as tissue remnants and periodontal ligament which were adhered to the root surface. Any calculus, present on the surface of the root was removed by using a gracey curette. The prepared samples were then stored in normal saline solution at 37ºC and at 95% humidity for a period of 15 days. Then the access cavity was prepared and the working length was determined with the help of routine radiographs. The canal shaping was done by using protaper rotary file system upto to 30 size by means of the crowndown technique. 2ml of 2.5% of sodium hypochlorite solution was used as the irrigant between filing followed by 5ml of 17% EDTA solution to remove the smear layer and then 2.5 ml of saline solution was used as final flush.

Then a preoperative CBCT analysis was done to evaluate the volume of the root canal after standardizing the working length as 15mm.This 15mm is further divided into coronal, middle and apical segments of 5mm each. These 5mm segments are further divided into 0.5mm slices. The prepared root canals were then dried with the appropriately sized paper points. AH plus sealer was coated along the walls of the prepared canals using lentulospiral. Before obturation the samples were randomly divided into four groups group I (CLC) was obturated with Lateral Compaction technique, group II(GF) was obturated with Guttaflow, group III(TF) was obturated with Thermafill and group IV(BF) with Beefill by following manufacturers instructions. Then the postoperative CBCT analysis was performed. Volume of each segment was then calculated from the linear measurements obtained from the CBCT analysis.

The volume of the root canal in each slice was then calculated by multiplying the root canal area by the slice thickness (0.5mm).The volume percentage of the voids in the obturated root canal (**VP**) was calculated by using the formula, (**R-V**) ×100/**R** where, **R** is the volume of the root canal space and **V** is the volume of the void space. From this formula the volume percentage of the obturated material was calculated. The homogeneity of obturation was then evaluated by estimating the prevalence of the voids at the coronal, middle and apical segments of the obturated root canals.

Data was analyzed statistically by using the Statistical Package for Social Sciences, (SPSS) version – 17 Software for Windows. Data entry was done with the Microsoft office Excel spreadsheet where data was analyzed using ANOVA and multiple comparisons by Post Hoc Bonferroni test. Voids were present in all the groups but no statistically significant difference was found among the groups. In the intergroup comparison of the overall total volume percentage between the four groups, the mean overall total volume percentage of the Lateral Compaction group was the lowest 88.9407% and Beefill 97.9273 % was the highest, which was statistically significant. For the presence of extrusion among the four groups, the mean value for Lateral Compaction was 3.07 and for Beefill the mean value was 1.033 which was also statistically significant.Within the limitations of the present study, it can be concluded that, the voids were present in all the four groups. The maximum volume percentage of obturated material was found in Beefill (97.9273%) and the least volume percent was in the Lateral Compaction technique (88.940%).

Extrusion was present in the Lateral Compaction group. Beefill showed better homogeneity and quality of obturation followed by Thermafill, Guttaflow and Lateral Compaction group.

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Thirurajapuram, Kavalkinaru,Jn – 627 105, Tirunvelveli District.

DCI Recognition No : DE-3(44)-93/2246 Dated 09-11-1993

Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai

This ethical committee has undergone the research protocol submitted by **Dr.S.Sherin Menaka**, Post Graduate Student, Dept of Conservative Dentistry and Endodontics under the title **"COMPARATIVE EVALUATION OF HOMOGENEITY AND QUALITY OF OBTURATION BY DIFFERENT OBTURATION TECHNIQUES USING CONE BEAM COMPUTED TOMOGRAPHY-AN IN VITRO STUDY"** under the guidance of **Dr.A.Arvind Kumar** for consideration of approval to proceed with the study.

This committee has discussed about the material being involved with the study, the qualification of the investigator, the present norms and recommendation from the Clinical Research scientific body and comes to a conclusion that this research protocol fulfills the specific requirements and the committee authorizes the proposal.

Dr. I. PACKIARAJ MDS,

CHAIR PERSON,

Ethical Committee.

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Dr.I.Packiyaraj, Chair person

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